April 2013 C11089_NGU

AIRBORNE MAGNETIC AND RADIOMETRIC SURVEY
NORGES GEOLOGISKE UNDERSØKELSE (NGU)

CALIBRATION REPORT

FRAS Campaigns
NORWAY 2011-2012

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ABSTRACT

This calibration report compiled the test and calibration results performed during the operations. Results were digitally recorded and could be sent upon request from the client. All the results were GPS processed prior to calculation.

Part A and B contain calibration results obtain for PA31 C-FWNG and PA31 C-GJDD respectively. No equipment have been changes, modified or swapped during the whole survey period. The calibration tests involved the following instruments.

- Three **Geometrics** G-822A Cesium optical vapour pumping magnetometers of the last generation, installed inside the stinger and inside the extensions of the wing-tip pods of the aircraft;
- Three **Radiation Solutions Inc**. (**RSI**) RS-500 Digital Airborne Gamma-Ray Spectrometers for the detection and measurement of low level radiation from naturally occurring sources. Each spectrometer includes 5 crystals RSX-5 detector: 16.72 litres (1024 in^3) NaI detector downward looking, plus a 4.18 litres (256 in^3) upward looking.
- A **NOVATEM** data-acquisition and compensator system unit, especially developed by **NOVATEM** for the Very High Resolution, based on the use of an inertial measurement unit and very robust inversion algorithms for the calculation of coefficients.
- An Inertial Measurement Unit (IMU) manufactured by **Honeywell**, providing the attitude angles of the aircraft (roll, pitch, yaw) in real time for both the compensation and the correction of the gradients.
- An orientation sensor (3DM) manufactured by **MicroStrain** , which incorporates 3 accelerometers and 3 magnetometers together, providing the attitude angles of the aircraft (roll, pitch, yaw) in real time for both the compensation and the correction of the gradients.
- A very high-resolution laser altimeter manufactured by **Optech**, integrated inside the rear of the aircraft. It measures the height of the aircraft above the ground with a precision of one centimetre, without calibration;
- A **TRA 4000** radar altimeter manufactured by **Free Flight Systems**, integrated below the aircraft, to measure the height of the aircraft above the ground when the clearance is too high for the laser (sharp valley);
- A double frequency **Novatel** Propack-V3 GPS providing a in real-time positioning with an accuracy of about one meter. The differential corrections are recomputed after the flights using the Waypoint GrafNav software to provide centimetre accuracy;
- A very efficient draping navigation system jointly developed by **Softnav** and **NOVATEM** to minimize the differences at the intersections of the flight lines and the control lines;
- Due to the large scale of the survey and restraint access to islands, the installation of several base stations was problematic. However, , two permanent base stations managed by the Tromsø Geophysical Observatory at University of Tromsø and three permanent base stations managed by IMAGE (International Monitor for Auroral Geomagnetism Effects) surrounding the survey area were also used to cover the entire survey area during all the survey operation.

Data compilation and results analysis were done by Pierrick Chasseriau, PhD. for **NOVATEM INC**.

A. BASE STATIONS SYNCHRONISATION AND AIRCRAFTS CONSISTENCY

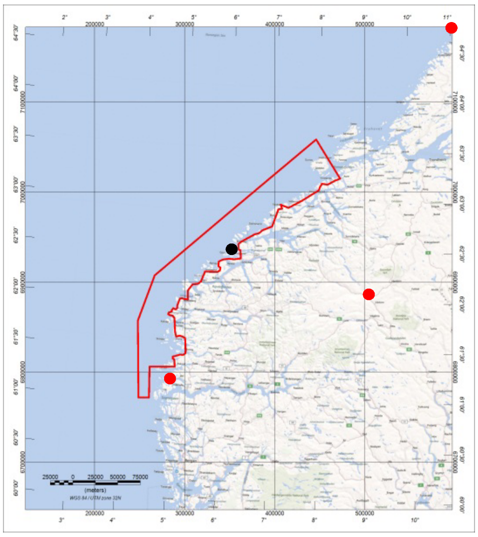
Date: 2012.02.07 - 2011.07.08

Location: Western NORWAY

Aircraft: PA31 **C-FWNG, C-GJDD**

Instrument: Magnetometer stations: GSM-19 Overhauser, **1Hz**
Magnetometers onboard: G-823 Cesium magnetometer, **10Hz**

Locations: NOVATEM station: Vigra, NORWAY; 6.0755743 62.5661829
TGO station: Solund, NORWAY; 4.8400 61.0870
TGO station: Dombas, NORWAY; 9.1100 62.0700
TGO station: Rorvik, NORWAY; 10.9872 64.9469



C-FWNG: MAGR1, 2, 3: Vigra Airport, NORWAY; 6.11022 62.55769

C-GJDD: MAGR1, 2, 3: Vigra Airport, NORWAY; 6.10988 62.55766

Concurrent measurements of magnetic base station and aircraft magnetometer were done during the night of the 7th of February thru the 8th of February 2012. 500000 readings have been recorded. For processing, the magnetic base stations were interpolated in two dimensions in order to get the best estimation at the position of the aircraft. Preliminary results have been given only with the diurnal correction from the station 1.

According to the specification of the contract, maximum allowed diurnal variation is 100nT/h, 35 nT/10 min and 15 nT/2 min. Nevertheless, since there are only few weeks available to fly the whole project, and taking into account that the base stations installed cover a large area, making the diurnal correction very accurate, days with little activity have been considered valid. Note that the base stations on the following graphics have the same dynamic range, centred for each profiles. Thus, the axis scale on the left represents only Novatem station at Vigra.

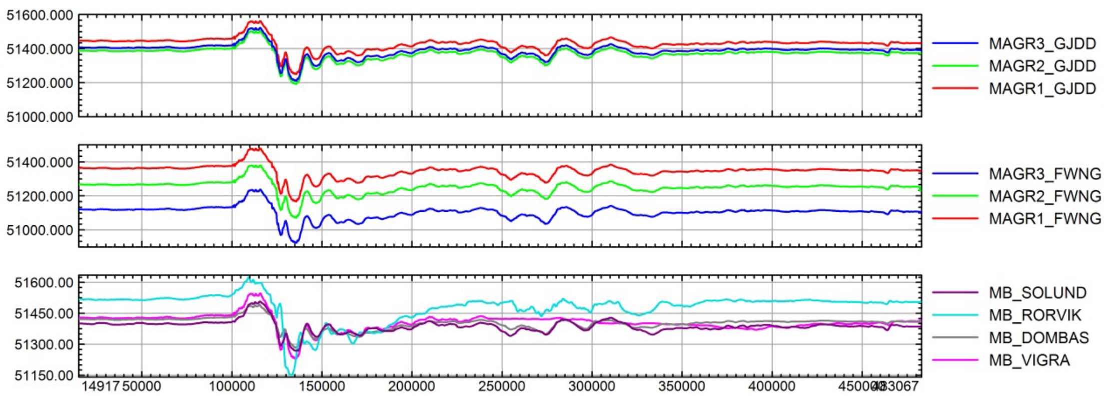


Figure 1: Magnetic base stations (MB) and aircrafts (C-GJDD, C-FWNG) synchronisation

CALIBRATION TESTS - C-FWNG

B. MAGNETOMETERS NOISE

Date: 2011.07.07

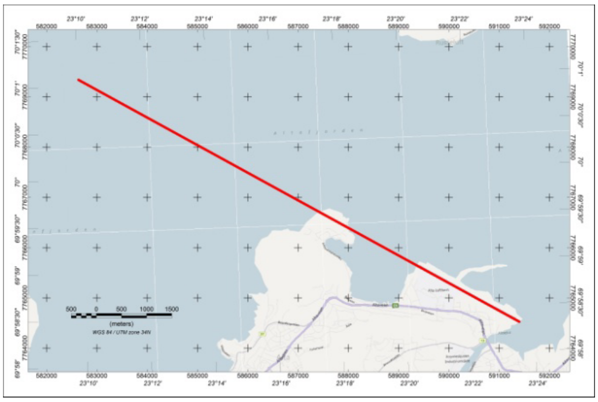
Location: Alta airport, NORWAY

Instruments: Magnetometers: G-823 Cesium magnetometer, **10Hz**

Temperature: 16.0 °C at sea level

Pressure: 101.4 kPa at sea level

Flying Height: 60 m



Noise level is evaluated on a test line over a distance greater than 4 km. For convenience, the 10 km test line used during the survey was then analysed for the purpose.

The graphic below shows the normalized fourth difference for each of the three magnetometers installed in the aircrafts. Requirement for the Finnmark campaign is 0.1 units fourth difference, which is clearly above the three mounted magnetometers evaluated.

MAGR1, 2 and 3 represents left, right and tail total raw magnetic field respectively.

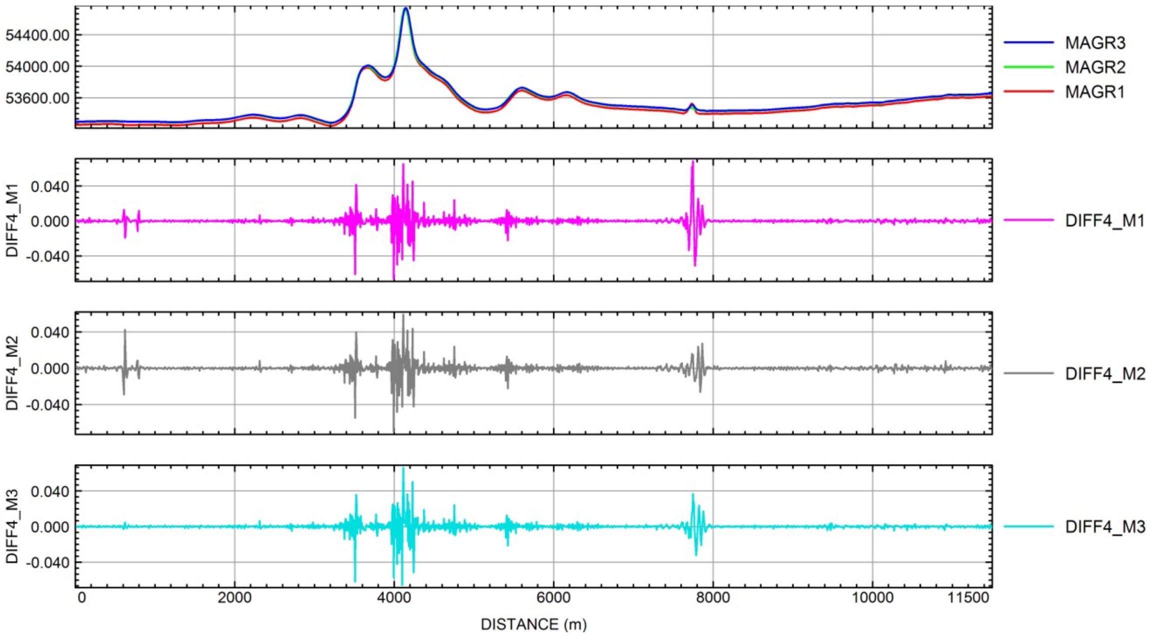


Figure 2: Magnetometers 4th difference

C. COMPENSATION BASED ON A PHYSICAL MODEL

Date: 2011.07.07

Location: North West of Alta, Norwegian Sea, NORWAY

Instruments: - Magnetometers onboard: G-823 Cesium magnetometer, **10Hz**
- Inertial measurement unit (IMU), Honeywell HG 1700 AG62, **10Hz**

Temperature: 16.0 °C at sea level

Pressure: 101.4 kPa at sea level

Flying Height: 3000 m

CALIBRATION FLIGHT (FOM)

In practice, the calibration flight follows a precise and reproducible geometry, called Figure of Merit (FOM) during which the aircraft describes successively three pitch oscillations (±5°), three roll oscillations (±10°) and three yaw oscillations (±5°) with a period of a few seconds. The four principal directions are described this way. The turns between each line are not taken into account for the calculation of the coefficients.

ESTIMATION OF THE COEFFICIENTS

The calculation of the coefficients is to determine the mathematical solution which minimizes the differences between the measured signals and those generated by the model. The disturbance field being described as a linear combination of the direction cosine and terrestrial field, the least square algorithm is particularly designated. The problems caused by the correlations between the columns of the matrix to inverse are easy to diagnose using the eigenvalues of the matrix. To do so, we calculate an index by submitting the ratio of the largest on the smallest eigenvalue. In practice, it is considered that this index should not exceed 10^3. In certain cases, we will be able to observe strong colinearities when certain variables are not used, such as the absence of eddy currents. An effective manner to solve this problem of multicollinearity consists in using the method known as regression ridge. In the case where the matrix is badly conditioned, then the coefficients have a variance much little than when a least square algorithm is used. The general idea is to shift the eigenvalues of the matrix by a small constant. Thus the largest eigenvalues, which have a real significance, are slightly modified, whereas the lowest eigenvalues - which cause problem at the inversion - are significantly modified. The implementation of the regression ridge thus allowed us to avoid the problems of numerical instability and to improve our algorithm.

RESULTS

The following figures show the results obtained by the calibration flights carried out at 3000m of altitude North West of Alta in the Norwegian Sea, NORWAY. As the blocks have different flight line orientations, two Figures of Merit were respectively flown according to the course:

Branch	FRASW – SAS	FRASE
Line 1	N 0	N 350
Line 2	N 270	N 260
Line 3	N 180	N 170
Line 4	N 90	N 80

Table 1 : FOM line directions

Flying the calibration figures in the same directions as the survey flight lines, we optimize the coefficients for these directions, as they are the one we will use.

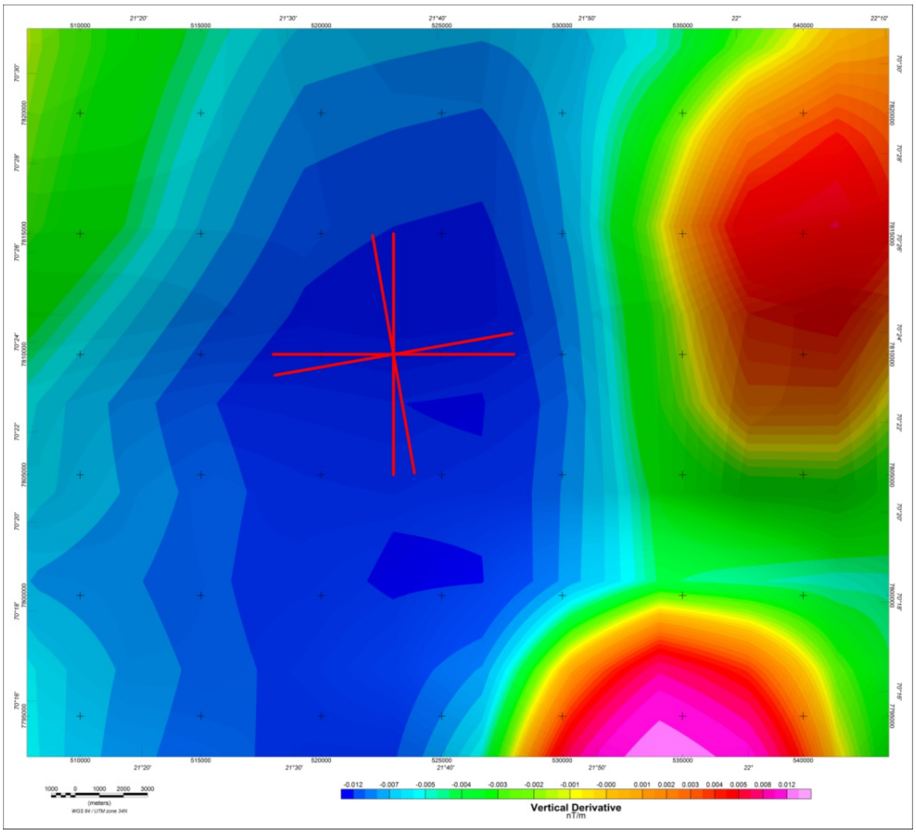


Figure 3 : Figure of merit over regional magnetic first vertical derivative

Each figure of merit includes 4 lines (L1, L2, L3 and L4) flown at high altitude, in an area with a low vertical gradient, and following a figure in a clover shape. Each line is thus flown in the two directions in respect with the direction of the lines and tie-lines.

D. HEADING AND ABSOLUTE ACCURACY TEST

Date: 2011.06.06

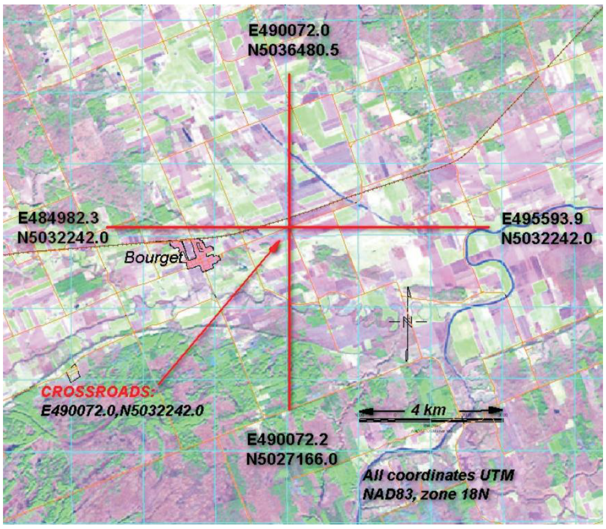
Location: Bourget, Quebec, CANADA

Instruments: Magnetometers: G-823
Cesium magnetometer, **10Hz**

Temperature: 20.0 °C at sea level

Pressure: 100.2 kPa at sea level

Flying Height: 305 m



This test is performed over an easily recognised point on the ground. The purpose is to ensure that aeromagnetic survey system measures the total field values with an absolute accuracy of 10nT or less after the aircraft has been compensated. The result from the test together with the FOM is also used to remove aircraft influence on magnetic data (heading error).

The following tables resume the values measured at the intersection of the lines, for the four directions and for the three magnetometers.

**AEROMAGNETIC SURVEY SYSTEM CALIBRATION TEST RANGES
AT BOURGET, ONTARIO AND MEANOOK, ALBERTA**

AIRCRAFT TYPE AND REGISTRATION: PIPER PA31 C-FWNG
ORGANIZATION (COMPANY): NOVATEM INC.
MAGNETOMETER TYPE: GEOMETRICS, **LEFT WING**
MAGNETOMETER SERIAL NUMBER:
COMPILED BY: OLIVIER SAVIGNET, ENG

DATE: 2011.06.06
HEIGHT FLOWN: 1000 FEET
SAMPLING RATE: 10 / SECOND
DATA ACQUISITION SYSTEM: NOVATEM INC.

Direction of flight across the Crossroads	Time that Survey Aircraft was over the Crossroads (HH/MM/SS) Greenwich Mean Time	Total Field Value (nT) Recorded in Survey Aircraft over Crossroads (T1)	Observatory Diurnal Reading at Previous Minute i.e. Hours + Minutes (T2) from Printout	Observatory Diurnal Reading at Subsequent Minute i.e. H hours + (M + 1) mins. (T3) from Printout	Interpolated Observatory Diurnal Reading at Time H hours + M mins + S sec T4 = T2 + S (T3 – T2) / 60	Calculated Observatory Value T5 = T4 - C*	Error Value T6 = T1 - T5
NORTH	14:34:23.4	54315.92	54903.45	54904.47	54903.49	54353.49	-37.57
SOUTH	14:16:02.9	54315.55	54906.90	54907.15	54906.98	54356.98	-41.43
EAST	14:26:04.9	54310.94	54905.21	54903.13	54904.79	54354.79	-43.85
WEST	14:08:22.1	54328.48	54907.43	54907.42	54907.43	54357.43	-28.95
NORTH							
SOUTH							
EAST							
WEST							

*C is the difference in the total field between the Blackburn or Meanook Observatory value (O) and the value (B) at the point above the crossroads at a given height. Blackburn Observatory: 1000 Feet, C = (O-B) = 550 nT; 500 Feet, C = 556 nT
Meanook Observatory: 1000 Feet, C = (O-B) = 0 nT; 500 Feet, C = 0 nT

Total = -151.80 nT

Average North-South Heading Error (T6 North - T6 South) = **3.86 nT**
Average East-West Heading Error (T6 East - T6 West) = **-14.90 nT**

Number of Passes for Average = -37.95 nT

novatem airborne geophysics

AEROMAGNETIC SURVEY SYSTEM CALIBRATION TEST RANGES
AT BOURGET, ONTARIO AND MEANOOK, ALBERTA

AIRCRAFT TYPE AND REGISTRATION: PIPER PA31 C-FWNG
ORGANIZATION (COMPANY): NOVATEM INC.
MAGNETOMETER TYPE: GEOMETRICS, **RIGHT WING**
MAGNETOMETER SERIAL NUMBER:
COMPILED BY: OLIVIER SAVIGNET, ENG

DATE: 2011.06.06
HEIGHT FLOWN: 1000_FEET
SAMPLING RATE: 10 / SECOND
DATA ACQUISITION SYSTEM: NOVATEM INC.

Direction of flight across the Crossroads	Time that Survey Aircraft was over the Crossroads (HH/MM/SS) Greenwich Mean Time	Total Field Value (nT) Recorded in Survey Aircraft over Crossroads (T1)	Observatory Diurnal Reading at Previous Minute i.e. Hours + Minutes (T2) from Printout	Observatory Diurnal Reading at Subsequent Minute i.e. H hours + (M + 1) mins. (T3) from Printout	Interpolated Observatory Diurnal Reading at Time H hours + M mins + S sec T4 = T2 + S (T3 – T2) ----- 60	Calculated Observatory Value T5 = T4 - C*	Error Value T6 = T1 - T5
NORTH	14:34:23.4	54341.16	54903.45	54904.47	54903.49	54353.49	-12.33
SOUTH	14:16:02.9	54345.89	54906.90	54907.15	54906.98	54356.98	-11.09
EAST	14:26:04.9	54350.27	54905.21	54903.13	54904.79	54354.79	-4.52
WEST	14:08:22.1	54342.58	54907.43	54907.42	54907.43	54357.43	-14.85
NORTH							
SOUTH							
EAST							
WEST							

*C is the difference in the total field between the Blackburn or Meanook Observatory value (O) and the value (B) at the point above the crossroads at a given height. Blackburn Observatory: 1000 Feet, C = (O-B) = 550 nT; 500 Feet, C = 556 nT
Meanook Observatory: 1000 Feet, C = (O-B) = 0 nT; 500 Feet, C = 0 nT Total = -42.79 nT

Average North-South Heading Error (T6 North - T6 South) = **-1.24** **nT**
Average East-West Heading Error (T6 East - T6 West) = **10.33** **nT**

Number of Passes for Average = -10.70 nT

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**AEROMAGNETIC SURVEY SYSTEM CALIBRATION TEST RANGES
AT BOURGET, ONTARIO AND MEANOOK, ALBERTA**

AIRCRAFT TYPE AND REGISTRATION: PIPER PA31 C-FWNG
ORGANIZATION (COMPANY): NOVATEM INC.
MAGNETOMETER TYPE: GEOMETRICS, **TAIL BOOM**
MAGNETOMETER SERIAL NUMBER:
COMPILED BY: OLIVIER SAVIGNET, ENG

DATE: 2011.06.06
HEIGHT FLOWN: 1000 FEET
SAMPLING RATE: 10 / SECOND
DATA ACQUISITION SYSTEM: NOVATEM INC.

Direction of flight across the Crossroads	Time that Survey Aircraft was over the Crossroads (HH/MM/SS) Greenwich Mean Time	Total Field Value (nT) Recorded in Survey Aircraft over Crossroads (T1)	Observatory Diurnal Reading at Previous Minute i.e. Hours + Minutes (T2) from Printout	Observatory Diurnal Reading at Subsequent Minute i.e. H hours + (M + 1) mins. (T3) from Printout	Interpolated Observatory Diurnal Reading at Time H hours + M mins + S sec T4 = T2 + S (T3 – T2) / 60	Calculated Observatory Value T5 = T4 - C*	Error Value T6 = T1 - T5
NORTH	14:34:23.4	54348.75	54903.45	54904.47	54903.49	54353.49	-4.74
SOUTH	14:16:02.9	54349.64	54906.90	54907.15	54906.98	54356.98	-7.34
EAST	14:26:04.9	54346.29	54905.21	54903.13	54904.79	54354.79	-8.5
WEST	14:08:22.1	54350.99	54907.43	54907.42	54907.43	54357.43	-6.44
NORTH							
SOUTH							
EAST							
WEST							

*C is the difference in the total field between the Blackburn or Meanook Observatory value (O) and the value (B) at the point above the crossroads at a given height. Blackburn Observatory: 1000 Feet, C = (O-B) = 550 nT; 500 Feet, C = 556 nT
Meanook Observatory: 1000 Feet, C = (O-B) = 0 nT; 500 Feet, C = 0 nT

Total = -27.02 nT

Average North-South Heading Error (T6 North - T6 South) = **2.60** **nT**
Average East-West Heading Error (T6 East - T6 West) = **-2.06** **nT**

Number of Passes for Average = -6.76 nT

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E. TEST LINE AND QC TESTS

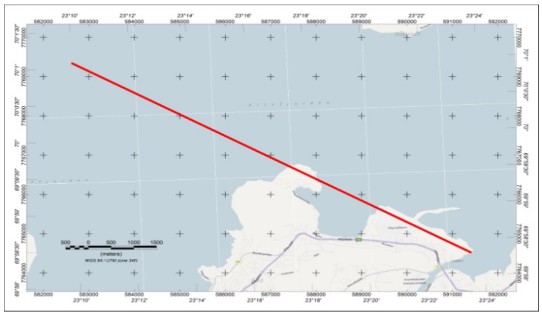
FRAS WEST

Date: 2011.06 – 2011.08

Location: Alta airport, NORWAY

Instrument: Spectrometer, RSI RSX500, 50.16L down, 12.54L up, **2Hz**

Flying Heights: 60m



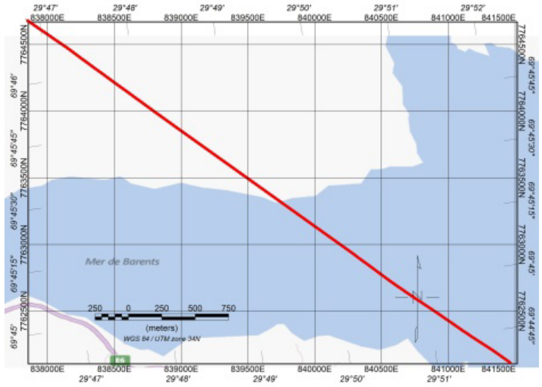
FRAS EAST

Date: 2012.06 – 2012.10

Location: Kirkenesairport, NORWAY

Instrument: Spectrometer, RSI RSX500, 50.16L down, 12.54L up, **2Hz**

Flying Heights: 60m



During the survey, quality control is carried out by the project manager on site. Controls on the quality are integrated in the normal process of acquisition and start as soon as the flight path is established and end at the delivery of the final products.

A survey test lines will be flown at the beginning of each flight as a check on system sensitivity, the stability of the magnetometers and spectrometers, and finally to monitor the effect of soil moisture in the area, (Variation of thorium concentration less than 10% after corrections on every flight).

Results will be presented in the Weekly Report as mean values difference over the average value measured within the duration of the project. The extension of the test line is about 10 km. The measurement over the water will be used for the calibration of the gamma ray upward looking detector.

After each flight, the raw data are inspected to make sure that there are no missing data or corrupted data. Data are then saved on an independent and secure location. For each flight, the following controls are then carried out in priority, to ensure:

- The deviations on both sides of the flight lines (±50m over 5000m)
- The altitude deviations of the flight lines (60m above the drape surface over 3000m)
- Spacing between each measurement (225 km/h ± 25 km/h over 5000m)
- The diurnal drifts (100 nT/h, 35 nT/10min, 15 nT/2min)
- The noise level of the data (Mean 4^{th} difference over 4000m less than 1.6)

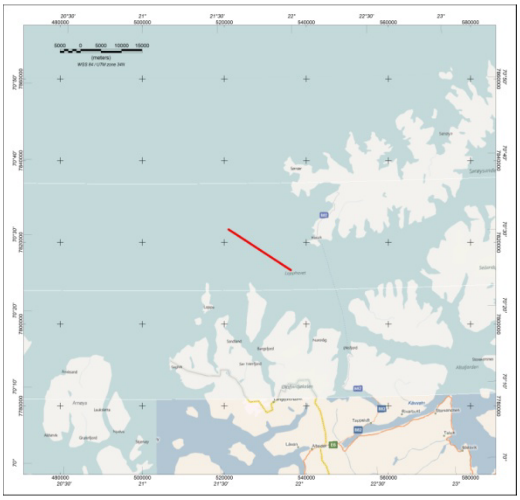
Quality control maps are then issued in the Weekly Report and sent to the NGU representative every weekend of the project duration.

Finally, the following radiometric checks are performed every morning to ensure spectra constancy and are included in the Weekly Report:

- Stabilisation better than ±25 keV measured on the 2.62 MeV ^{208}Tl peak
- FWHM better than 200 keV measured on the 2.62 MeV ^{208}Tl peak

- Careful verification of each profile (and spectra) to spot spikes, jumps or interruptions in the readings
- Statistical calculation of the mean spectra for each line to insure potassium and thorium peak stability (drift less than 4 channels on the thorium peak)
- Correction and gridding of preliminary grids to evaluate data coherence and consistency.

F. Cosmic and Aircraft Background Correction



Date: 2011.07.07

Location: North West of Alta, Norwegian Sea, NORWAY

Instrument: Spectrometer, RSI RSX500, 50.16L down, 12.54L up, **2Hz**

Temperature: 16.0 °C at sea level

Pressure: 101.4 kPa at sea level

Flying Heights: 1500m-3000m

To determine the cosmic and aircraft background, the spectrometer used records all incident particles above 3 MeV in the Cosmic channel. Steps are flown at 6 equidistant heights, from 1500m to 3000m and over the sea to reduce the presence of radon. Furthermore, in order to minimize statistical errors, each step is 18 km long and lasts around 8 minutes.

It was established that no radon contamination is notably apparent for which it would result in a breakdown of the linear relationship. Mean counts and linear relations of the cosmic radiations in the various spectral windows are represented below.

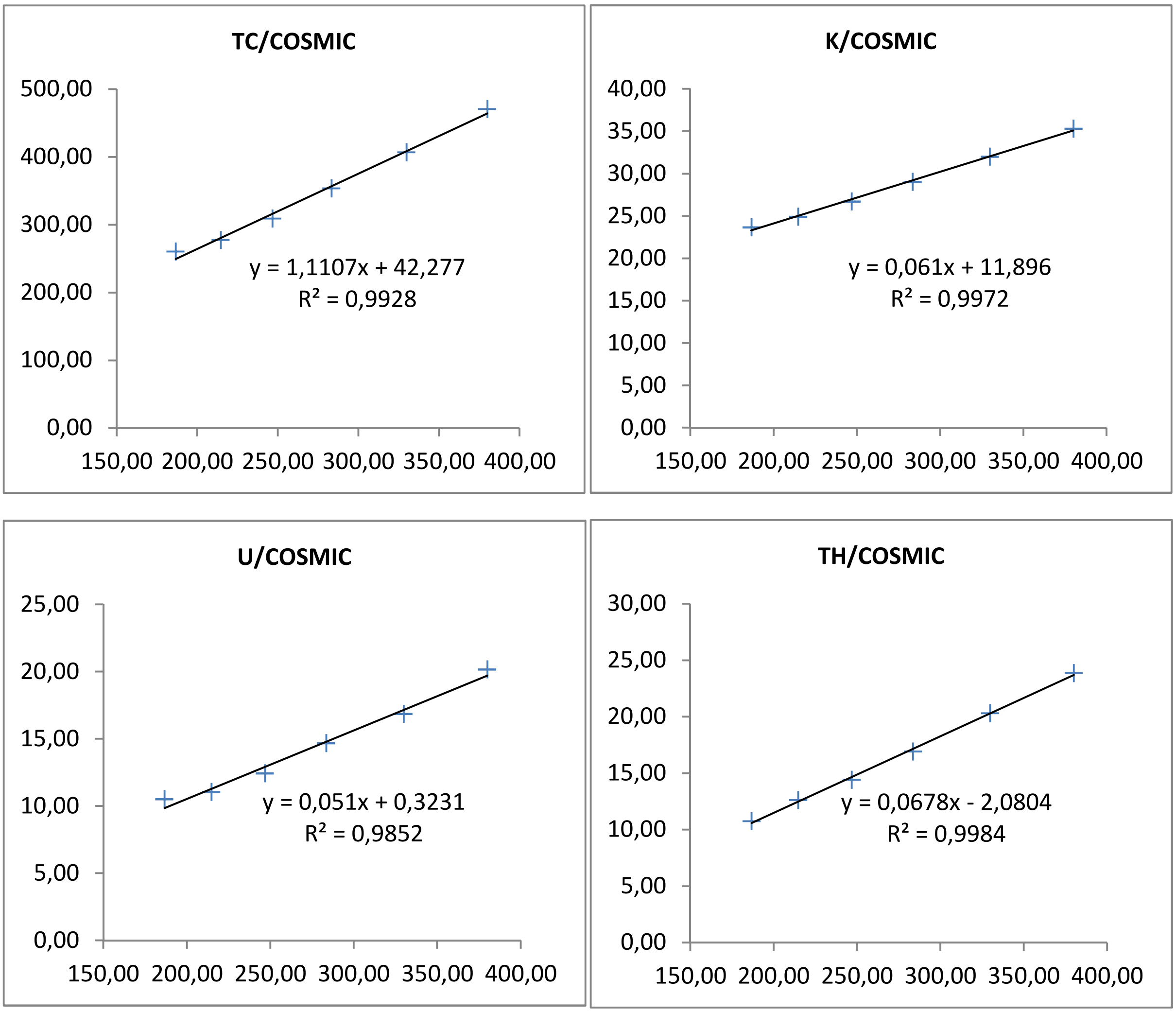
Altimeter (m)	Cosmic Dn	Cosmic Up	Total Count	Potassium	Uranium	Thorium	Up Uranium
1504.37	186.66	51.05	260.16	23.64	10.50	10.74	2.44
1803.73	214.62	58.67	277.09	24.90	11.04	12.62	2.75
2102.91	246.73	68.12	308.78	26.68	12.42	14.40	3.32
2400.89	283.39	78.02	353.45	29.01	14.67	16.90	3.82
2700.43	329.82	89.93	406.47	32.00	16.84	20.31	4.41
2998.63	380.02	105.18	470.56	35.28	20.16	23.85	5.35

Table 2 : Steps averaged data

Background	Total Count	Potassium	Uranium	Thorium	Up Uranium
Aircraft	42.3	11.9	0.3	-2.0	-0.4
Cosmic	1.110	0.061	0.051	0.068	0.054

Table 3 : Cosmic & Aircraft background coefficients

Notice that the coefficient of determination is remarkably high for every window. Lower coefficients would have been characteristic of the radon concentration variation in the air during the flight as the thorium window is less affected and the uranium and total count are closely correlated. However, the only effect of varying radon during the cosmic-ray calibration flights will be an unknown radon component which will be removed during radon processing, as it is demonstrated in *Grasty and Minty, AGSO 1995/60*.



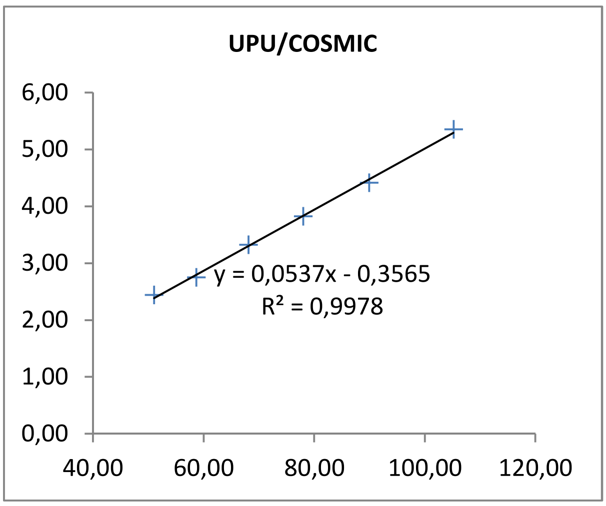


Figure 4 : Background correction

G. UPWARD LOOKING DETECTOR CORRECTION COEFFICIENTS

Location: Alta Bay, NORWAY, 2011

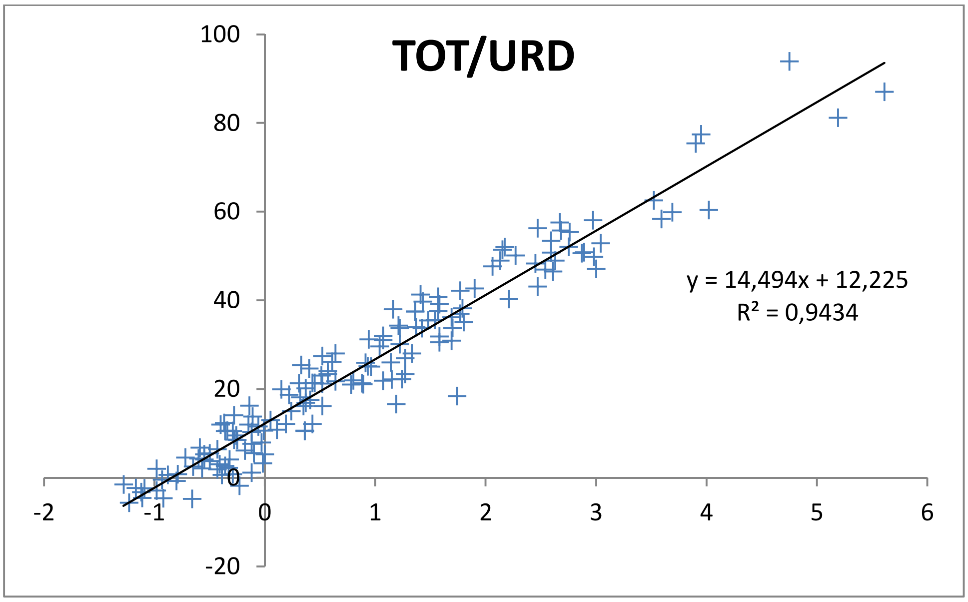
Instrument: Spectrometer: RSI RSX500, 50.16L down, 12.54L up, **2Hz**

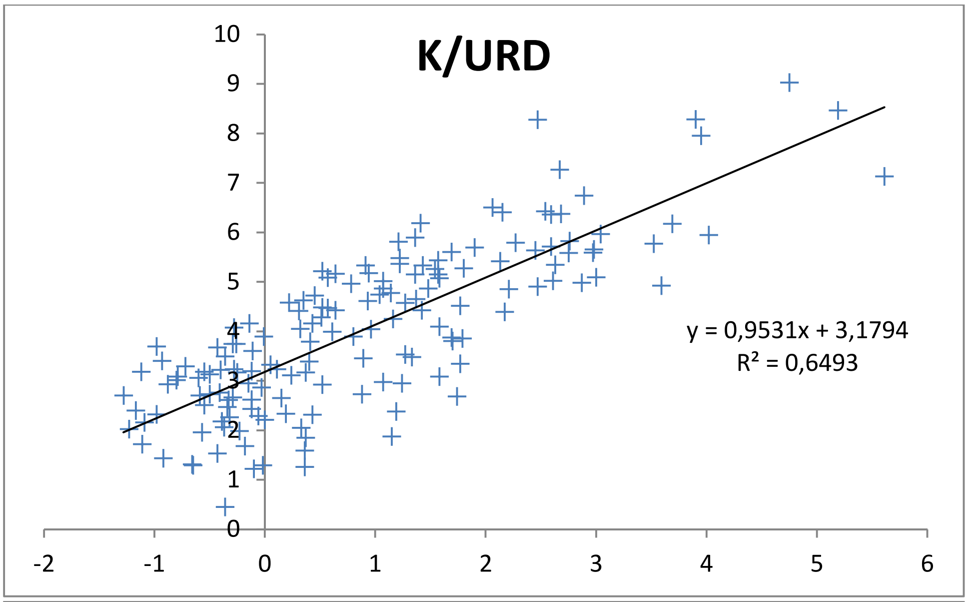
Flying Height: 60 m

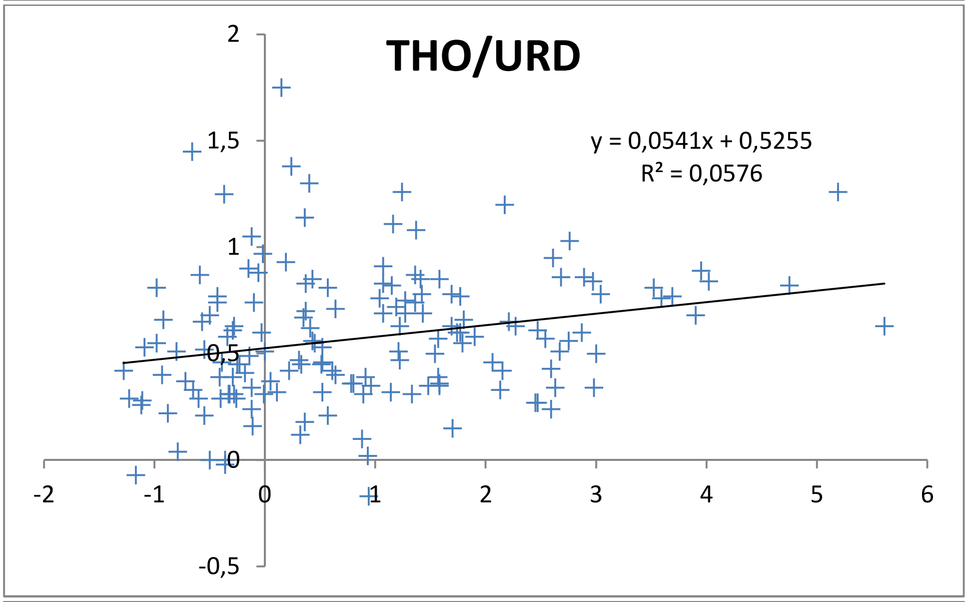
In order to determine the relationship between the upward and downward detector count rates for radon in the air, series of flights over water, where there is no contribution from the ground, will be done as a part of the test line. Due to the scale of the survey, a considerable amount of data is recorded close to the area. Location of the water surface is shown on the test line's map.

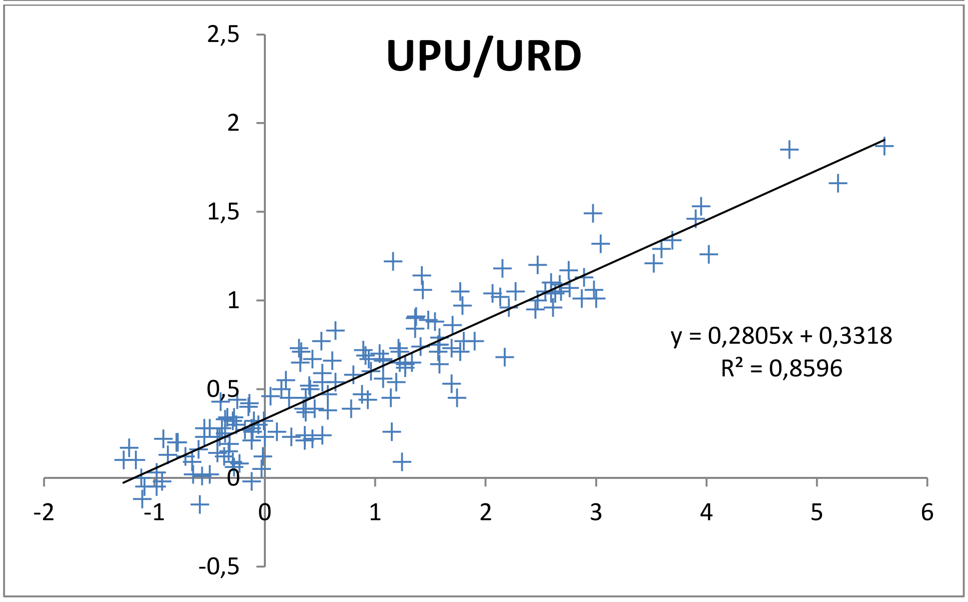
Prior to the analysis, aircraft background and cosmic component are removed and the dead time correction done. Since the cosmic and aircraft background calibration test leaded to highly reliable results, shown by the coefficients of determination R_2 in each window, we expect linear constants b_n to be close to zero. In addition, in order to minimize the statistical noise, only series over 20 valid counts are used. The results are presented in the following graphs.

Coefficients determined can have sometime a negative value. That can be explained by a variation of radon concentration during the calibration of the cosmic radiation. This unknown radon component is precisely removed by considering the given residual components at the time of the radon correction; results described in Grasty and Minty, AGSO 1995/60.




K/URD
y = 0,9531x + 3,1794
R² = 0,6493
10
9
8
7
6
5
4
3
2
1
0
-2
-1
0
1
2
3
4
5
6


THO/URD
y = 0,0541x + 0,5255
R² = 0,0576
2
1,5
1
0,5
0
-0,5
-2
-1
0
1
2
3
4
5
6


UPU/URD
y = 0,2805x + 0,3318
R² = 0,8596
2,5
2
1,5
1
0,5
0
-0,5
-2
-1
0
1
2
3
4
5
6

The constants above water for the four windows are:

$$a_u, b_u = 0.280, 0.33$$
$$a_K, b_K = 0.95, 3.18$$
$$a_{Th}, b_{Th} = 0.05, 0.52$$
$$a_{TC}, b_{TC} = 14.49, 12.22$$

The component of the upward detector count rate originating from the ground, u_g, will depend on the concentration of U an Th in the ground, as will the components of U and Th downward window count rates, U_g and Th_g, that originate from the ground. In order to minimize the statistical errors, the three components were calculated by subtracting flights above water present on Stad at the values adjacent on the firm ground. Numerous sites have thus been evaluated on the block. Finally, from the series of calculated values of U_g, U_g and Th_g, the calibration factors, a_1 and a_2, are determined by the least squares method described in IAEA Technical reports series No.323.

a_1	a_2
0.035	0.045

H. PADS CALIBRATION

RADIATION SOLUTIONS INC

CALIBRATION SHEET

Instrument: **RSX-5**

Customer:	Novatem		Date:	May 4, 2011
Contact:	Pascal Mouge		Tech.:	GP
Console :	N/A		Job Order:	SO#1947
Detector 1:	5578		Customer PO	PO#Email
Detector 2:	N/A			

Channels: 1024 **ADC Offset:** N/A

High Voltages	A1	A2	A3	A4	A5
	671	692	659	715	683

Stripping Constant	"this system"	"normal"
Alpha	**0.267**	0.250
Beta	**0.401**	0.400
Gamma	**0.764**	0.810
a	**0.047**	0.060
b	**-0.001**	0.000
g	**0.001**	0.003

ROI#	Channel	IAEA Specification [keV]	Label
1	137-937	410-2810	Total Count
2	457-523	1370-1570	Potassium K
3	553-620	1660-1860	Uranium U
4	803-937	2410-2810	Thorium Th
5			
6			
7			
8	553-620	1660-1860	Uranium Upper U

Det#	Peak Cs	Cs FWHM		Peak Th	Th FWHM
A1	219.86	7.15		872.88	4.06
A2	219.38	7.44		871.70	4.15
A3	219.67	7.36		872.60	4.01
A4	219.87	7.29		872.54	4.28
Sum Dn	**219.69**	**7.33**		**872.47**	**4.13**
Sum Up	**220.68**	**7.96**		**872.87**	**4.75**

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RADIATION SOLUTIONS INC

CALIBRATION SHEET

Instrument: **RSX-5**

Customer:	Novatem	Date:	May 4, 2011
Contact:	Pascal Mouge	Tech.:	GP
Console :	N/A	Job Order:	SO#1947
Detector 1:	5577	Customer PO	PO#Email
Detector 2:	N/A		

Channels: 1024 **ADC Offset:** N/A

	A1	A2	A3	A4	A5
High Voltages	683	680	680	701	704

Stripping Constant	"this system"	"normal"
Alpha	0.272	0.250
Beta	0.404	0.400
Gamma	0.766	0.810
a	0.048	0.060
b	0.003	0.000
g	-0.002	0.003

ROI#	Channel	IAEA Specification [keV]	Label
1	137-937	410-2810	Total Count
2	457-523	1370-1570	Potassium K
3	553-620	1660-1860	Uranium U
4	803-937	2410-2810	Thorium Th
5			
6			
7			
8	553-620	1660-1860	Uranium Upper U

Det#	Peak Cs	Cs FWHM		Peak Th	Th FWHM
A1	220.15	7.32		872.48	4.15
A2	220.00	7.52		872.35	4.24
A3	219.93	7.54		871.56	4.31
A4	219.00	7.40		872.06	4.14
Sum Dn	219.76	7.48		872.13	4.20
Sum Up	218.88	7.81		871.32	4.40

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RADIATION SOLUTIONS INC

CALIBRATION SHEET

Instrument: **RSX-5**

Customer: Novatem
Contact: Pascal Mouge
Console : N/A
Detector 1: 5510
Detector 2: N/A

Date: May 24, 2011
Tech.: GP
Job Order: SO#1947
Customer PO: PO#Email

Channels: 1024 **ADC Offset:** N/A

	A1	A2	A3	A4	A5
High Voltages	635	675	649	640	704

Stripping Constant	"this system"	"normal"
Alpha	**0.273**	0.250
Beta	**0.401**	0.400
Gamma	**0.771**	0.810
a	**0.047**	0.060
b	**0.000**	0.000
g	**-0.001**	0.003

ROI#	Channel	IAEA Specification [keV]	Label
1	137-937	410-2810	Total Count
2	457-523	1370-1570	Potassium K
3	553-620	1660-1860	Uranium U
4	803-937	2410-2810	Thorium Th
5			
6			
7			
8	553-620	1660-1860	Uranium Upper U

Det#	Peak Cs	Cs FWHM		Peak Th	Th FWHM
A1	221.02	7.29		871.80	4.08
A2	221.07	7.32		871.65	4.20
A3	220.71	7.48		871.72	4.23
A4	221.04	7.23		872.28	4.08
Sum Dn	**220.96**	**7.33**		**871.86**	**4.14**
Sum Up	**221.56**	**7.46**		**872.41**	**4.26**

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I. HEIGHT ATTENUATION & SENSITIVITY

Date: 2011.06.06

Location: Breckenridge, Quebec, CANADA

Instruments: - Novatem Inc., RSX500, 50.16L down, 12.54L up, **2Hz**
- Geological Survey of Canada, Portable spectrometer for ground measurements

Test Area: TC=54.94 nGy/h, K= 1.96%, eU= 1.55ppm, eTh= 8.20ppm

Temperature: 20°C at sea level

Pressure: 100.2 kPa at sea level

Flying Height: 50-230m

Altimeter (m)	STP Corrected	Total Count	Potassium	Uranium	Thorium
49.21	46.69	1704.62	215.03	32.9	45.89
79.98	75.75	1420.12	170.74	28.78	38.34
108.65	102.88	1207.29	139.5	24.94	32.29
138.35	130.6	1038.56	115.03	23.03	27.6
167.01	157.21	906.02	96.63	21.06	24.87

Table 4 : Test Data (cps)

Altimeter (m)	STP Corrected	Total Count	Potassium	Uranium	Thorium
56.29	50.6	206.23	22.74	8.43	6.28
86.83	78.94	206.74	21.54	8.37	6.11
118.26	106.93	208.69	22.28	9.08	5.9
146.52	133.03	209.99	22.23	8.76	7.02
174.34	159.15	209.25	22.14	9.01	6.92

Table 5 : Background Data (cps)

α	β	γ	a	b	g
0.271	0.402	0.767	0.047	0.001	- 0.001

Table 6 : Stripping ratios

Total Count	Potassium	Uranium	Thorium
1498.39	171.71	13.55	39.78
1213.38	131.74	11.07	32.38
998.6	103.29	7.82	26.59
828.57	80.51	7.79	20.66
696.77	63.84	6.14	18.06

Table 7 : Background-Corrected & Stripped Counts (cps))

After dead time correction, mean count rates of all four windows are then corrected from the cosmic radiation, atmospheric radioactivity and aircraft background by subtracting adjacent values over water. STP corrected Compton stripping ratios are then applied to the count rates. The stripped count rates at each altitude are finally fitted to the exponential function to give the height attenuation coefficients. Figure 1 shows the curves for all four windows, determined from the test strip.

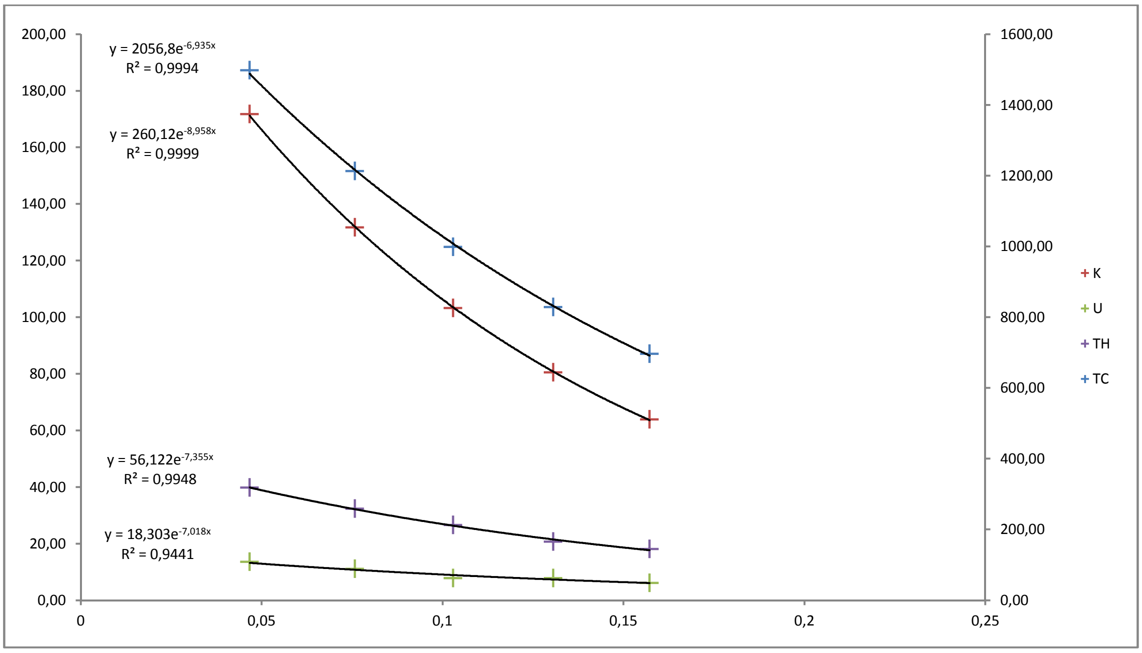


Figure 5 : Exponential height attenuation for all four windows

Broad source sensitivity for each window was calculated using concentration of the radioelement measured at ground level on the strip and for a final STP height of 60m. All the results are shown in table 17.

	Total Count	Potassium	Uranium	Thorium
ATTENUATION	-0.00693 m^{-1}	-0.00895 m^{-1}	-0.00702 m^{-1}	-0.00735 m^{-1}
SENSITIVITY	24.7 cps/ nGy/h	77.5 cps/%	7.73 cps/ppm	4.4 cps/ppm

Table 8 : Attenuation coefficients & Sensitivity (60m)

J. LAG TEST

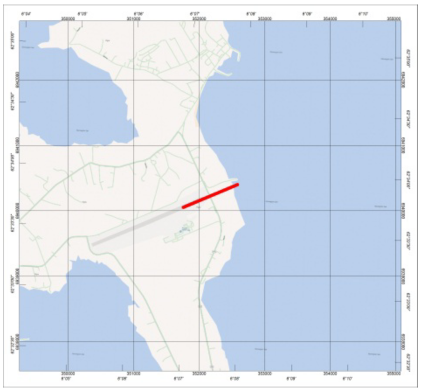
Date: 2012.02.15

Location: Flyplasstunnelen, Fv137
Vigra Airport, NORWAY

Aircraft: PA31 **C-FWNG**

Instrument: Magnetometers: G-823 Cesium magnetometer, **10Hz**

Heights: 60 m



Taking into account the spatial difference between the GPS antenna and the different magnetometers, the following results show that there is almost no time lag in the data records. Note that the spatial lag will be taking into account in the processing in order to replace each magnetometer in the space for gradient enhancement.

MAG 1 (Left wing tip pod)

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L1:0	70	60.32	64.79	143856.7	352159.7	6940220.8	58.9	51657.510
L2:0	250	245.78	62.95	144054.2	352151.4	6940221.2	61.7	51673.150

MEAN SPEED = 60.3 m/s
DISTANCE = 8.350 m
LAG = 0.069 sec

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L3:0	70	61.64	60.47	144312.6	352164.6	6940221.7	56.1	51694.060
L4:0	250	244.80	62.90	144523.1	352149.6	6940221.0	58.9	51671.060

MEAN SPEED = 57.5 m/s
DISTANCE = 14.996 m
LAG = 0.130 sec

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L5:0	68	71.61	276.038	71259.3	609880.28	7825645.32	64.17	1.086
L6:0	248	249.12	271.848	71534.5	609891.43	7825659.32	68.62	1.567

MEAN SPEED = 57.6 m/s
DISTANCE = 12.398 m
LAG = 0.108 sec

MAG 2 (Right wing tip pod)

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L1:0	70	60.32	64.79	143856.7	352159.7	6940220.8	58.9	51682.470
L2:0	250	245.78	62.95	144054.2	352151.4	6940221.2	61.7	51699.550

MEAN SPEED = 60.3 m/s
DISTANCE = 8.350 m
LAG = 0.069 sec

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L3:0	70	61.64	60.47	144312.6	352164.6	6940221.7	56.1	51710.720
L4:0	250	244.80	62.90	144523.1	352149.6	6940221.0	58.9	51697.300

MEAN SPEED = 57.5 m/s
DISTANCE = 14.996 m
LAG = 0.130 sec

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L5:0	70	61.19	61.92	144742.0	352165.0	6940220.6	56.7	51697.450
L6:0	250	244.48	64.26	144954.7	352153.8	6940215.2	58.6	51699.840

MEAN SPEED = 57.6 m/s
DISTANCE = 12.398 m
LAG = 0.108 sec

MAG 3 (Tail boom)

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L1:0	70	60.66	64.84	143856.9	352170.6	6940225.3	58.9	51687.020
L2:0	250	245.69	62.89	144054.3	352145.6	6940218.9	61.7	51700.870

MEAN SPEED = 60.3 m/s
DISTANCE = 25.767 m
LAG = 0.214 sec

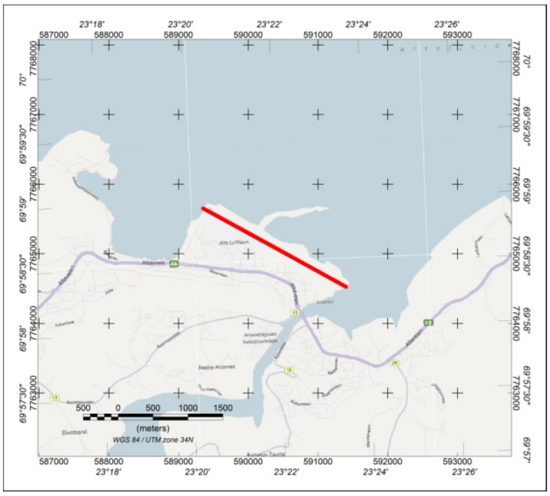
LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L3:0	70	61.53	60.44	144312.7	352169.8	6940223.8	56.1	51718.830
L4:0	250	244.89	62.77	144523.2	352144.2	6940218.7	58.9	51701.230

MEAN SPEED = 57.5 m/s
DISTANCE = 26.113 m
LAG = 0.227 sec

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L5:0	70	61.23	61.93	144742.1	352170.2	6940222.8	56.9	51708.410
L6:0	250	244.53	64.23	144954.8	352148.4	6940213.0	58.6	51689.800

MEAN SPEED = 57.8 m/s
DISTANCE = 23.920 m
LAG = 0.207 sec

K. LASER AND RADAR CALIBRATION



Date: 2011.07.10

Location: Alta airport (alt: 2.74 m), NORWAY

Instrument: - GPS receiver: Novatel Propak – V3, **10Hz**
- Laser altimeter: Optech Sentinel 3100, **10Hz**
- Radar altimeter: Free Flight TRA 4000, **10Hz**

Temperature: 21.1 °C at sea level

Pressure: 101.1 kPa at sea level

Flying Heights: 40m-180m

To determine coefficients of calibration for the laser and radar altimeter, steps are flown at 5 different heights, from 40m to 180m and over the Alta airport strip in order to have a surface as flat as possible for the calibration. In order to minimize errors, each step is 2 km long.

The different altitudes recorded show a perfect linearity with the post processed GPS altitude. The airport altitude (2.75 m) was removed from the mean altitude recorded in order to evaluate the results. Finally, linear relations between the different altimeters are plotted below and calibration constants needed for processing are provided.

GPS altitude	Adjusted GPS altitude (m)	Laser altitude (m)	Radar altitude (m)
40.55	37.80	37.38	37.66
89.80	87.05	86.73	88.14
119.92	117.17	116.93	119.02
149.39	146.64	146.35	149.26
179.79	177.04	176.80	180.60

Table 9: Radar calibration

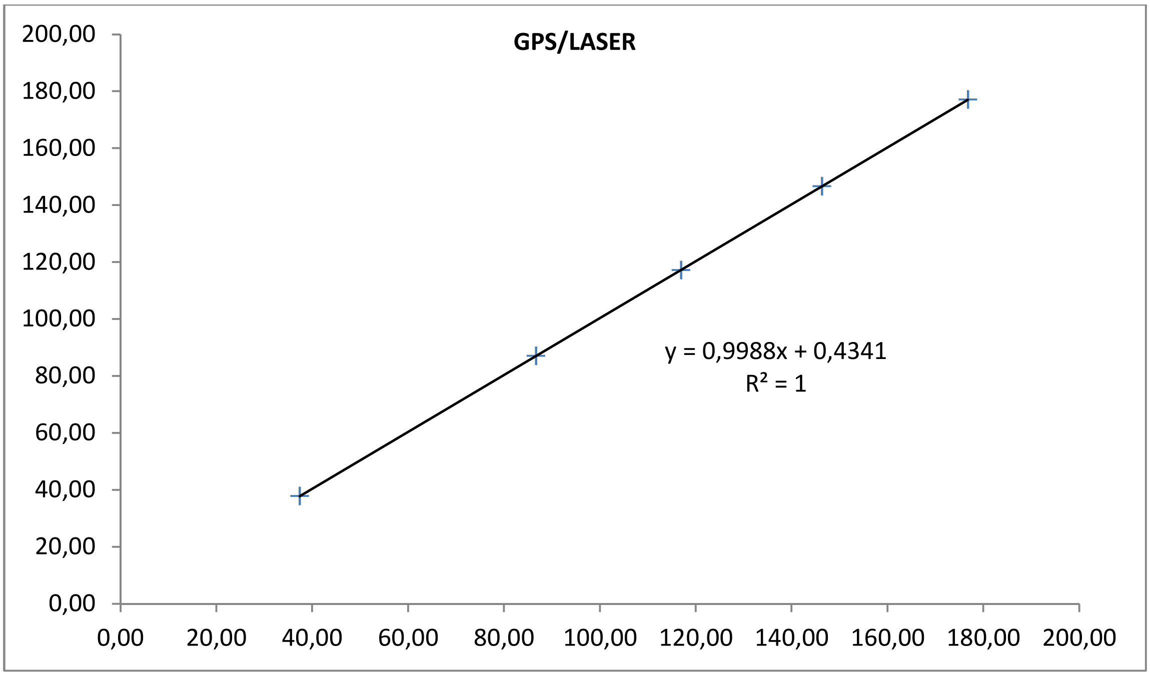


Figure 6 : Laser calibration

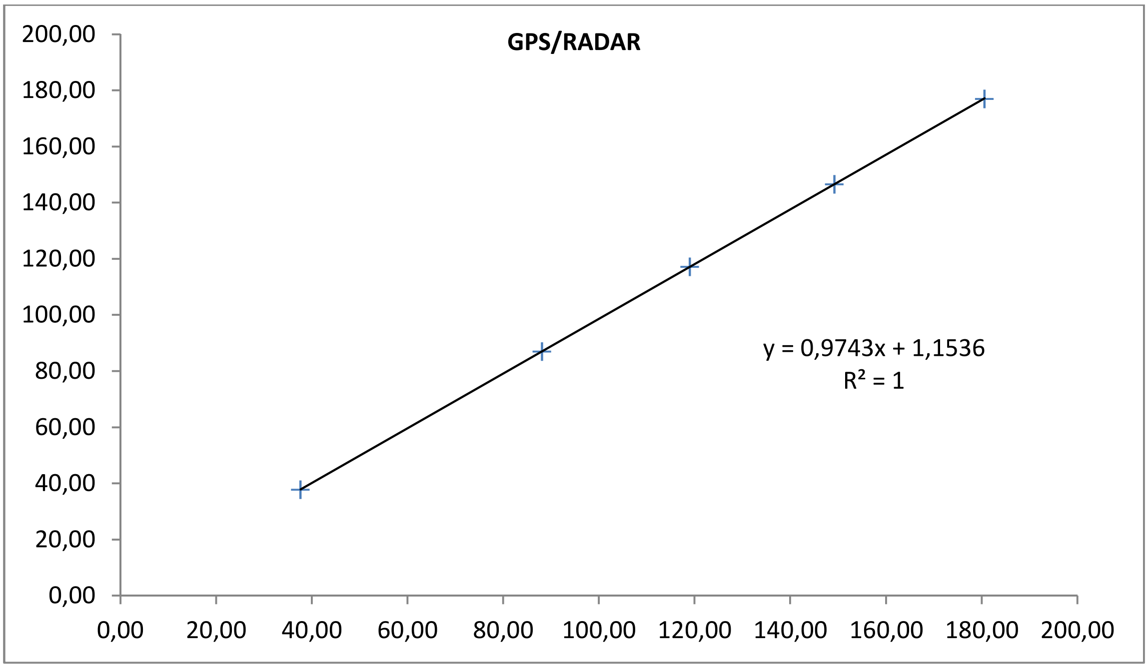


Figure 7 : Radar calibration

CALIBRATION TESTS - C-GJDD

B. MAGNETOMETERS NOISE

Date: 2011.11.01

Location: Vigra airport, Ålesund NORWAY

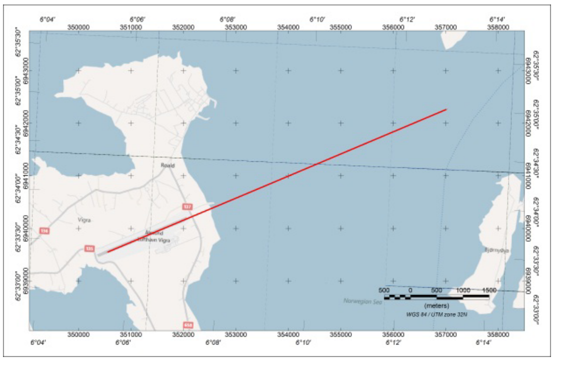
Aircraft: PA31 **C-GJDD**

Instruments: Magnetometers: G-823 Cesium magnetometer, **10Hz**

Temperature: 17.8 °C at sea level

Pressure: 998.5 kPa at sea level

Height: 60 m



Noise level is evaluated on a test line over a distance greater than 4 km. For convenience, the 7 km test line used during the survey was then analysed for the purpose.

The graphic below shows the normalized fourth difference for each of the three magnetometers installed in the aircrafts. Requirement for the Stad campaign is 0.1 units fourth difference, which is clearly above the three mounted magnetometers evaluated.

MAGR1, 2 and 3 represents left, right and tail total raw magnetic field respectively.

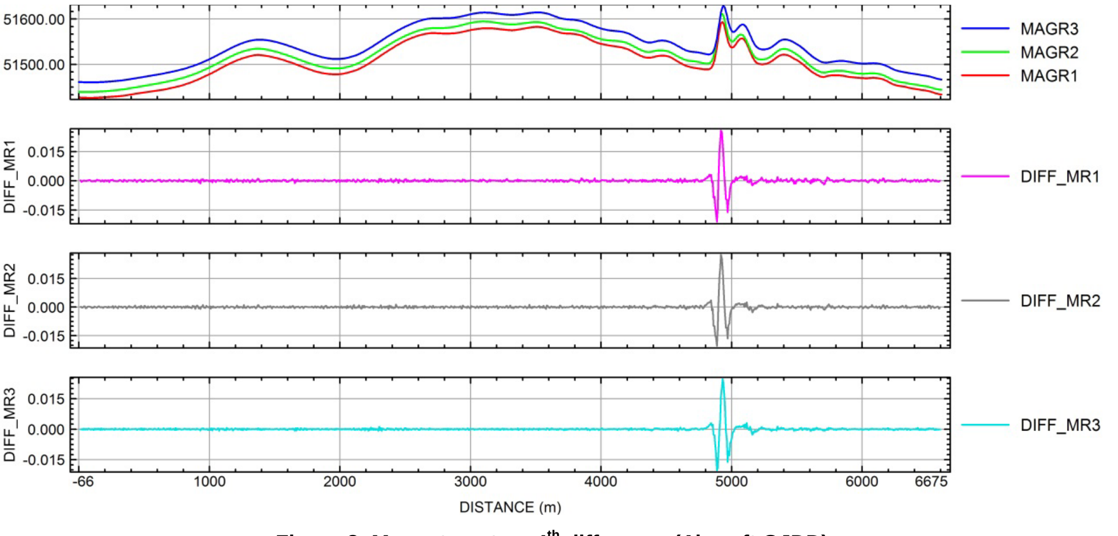


Figure 8: Magnetometers 4th difference (Aircraft GJDD)

C. COMPENSATION BASED ON A PHYSICAL MODEL

Date: 2012.10.02

Location: North West of Alta, Norwegian Sea, NORWAY

Aircraft: PA31 **C-GJDD**

Instrument: Magnetometers onboard: G-823 Cesium magnetometer, **10Hz**
Inertial measurement unit (IMU), Honeywell HG 1700 AG62, **10Hz**

Temperature: 9.8°C at sea level

Pressure: 100.5 kPa at sea level

Height: 3000 m

CALIBRATION FLIGHT (FOM)

In practice, the calibration flight follows a precise and reproducible geometry, called Figure of Merit (FOM) during which the aircraft describes successively three pitch oscillations (±5°), three roll oscillations (±10°) and three yaw oscillations (±5°) with a period of a few seconds. The four principal directions are described this way. The turns between each line are not taken into account for the calculation of the coefficients.

ESTIMATION OF THE COEFFICIENTS

The calculation of the coefficients is to determine the mathematical solution which minimizes the differences between the measured signals and those generated by the model. The disturbance field being described as a linear combination of the direction cosine and terrestrial field, the least square algorithm is particularly designated. The problems caused by the correlations between the columns of the matrix to inverse are easy to diagnose using the eigenvalues of the matrix. To do so, we calculate an index by submitting the ratio of the largest on the smallest eigenvalue. In practice, it is considered that this index should not exceed 10^3. In certain cases, we will be able to observe strong colinearities when certain variables are not used, such as the absence of eddy currents. An effective manner to solve this problem of multicollinearity consists in using the method known as regression ridge. In the case where the matrix is badly conditioned, then the coefficients have a variance much little than when a least square algorithm is used. The general idea is to shift the eigenvalues of the matrix by a small constant. Thus the largest eigenvalues, which have a real significance, are slightly modified, whereas the lowest eigenvalues - which cause problem at the inversion - are significantly modified. The implementation of the regression ridge thus allowed us to avoid the problems of numerical instability and to improve our algorithm.

RESULTS

The following figures show the results obtained by the calibration flights carried out at 3000m of altitude North West of Vigra in the Norwegian Sea, NORWAY. As the blocks have different flight line orientations, two Figures of Merit were respectively flown according to the course:

Branch	SAS
Line 1	N 0
Line 2	N 270
Line 3	N 180
Line 4	N 90

Table 10 : FOM line directions

Flying the calibration figures in the same directions as the survey flight lines, we optimize the coefficients for these directions, as they are the one we will use.

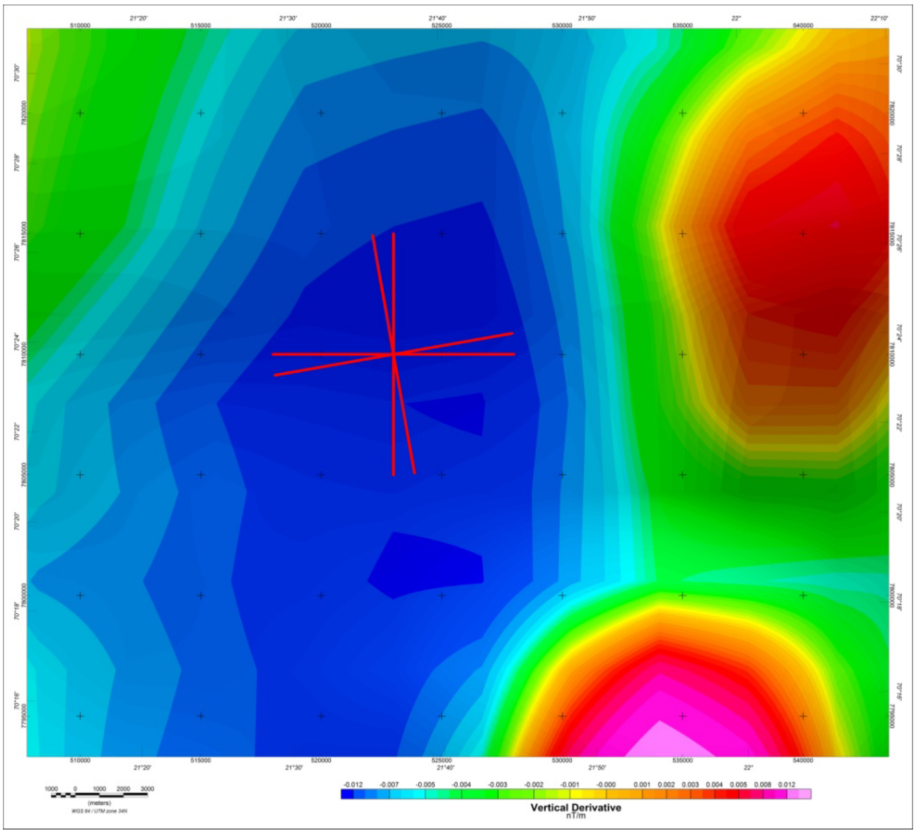


Figure 9 : Figure of merit over regional magnetic first vertical derivative

Each figure of merit includes 4 lines (L1, L2, L3 and L4) flown at high altitude, in an area with a low vertical gradient, and following a figure in a clover shape. Each line is thus flown in the two directions in respect with the direction of the lines and tie-lines.

D. HEADING AND ABSOLUTE ACCURACY TEST

Date: N/A

Location: Bourget, Quebec, CANADA

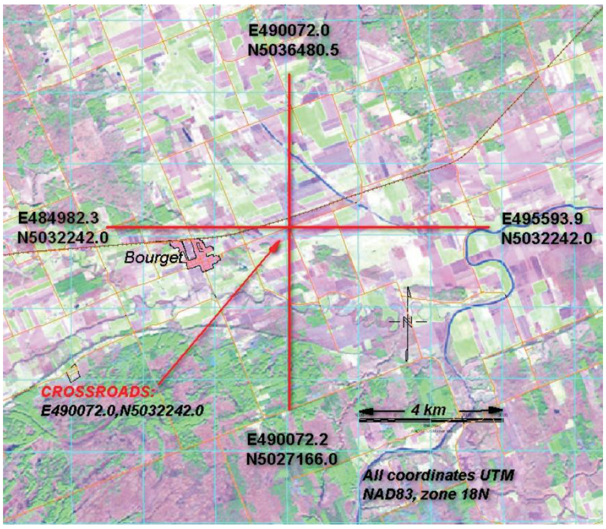
Aircraft: PA31 **C-GJDD**

Instrument: Magnetometers: G-823 Cesium magnetometer, **10Hz**

Temperature: N/A

Pressure: N/A

Height: N/A



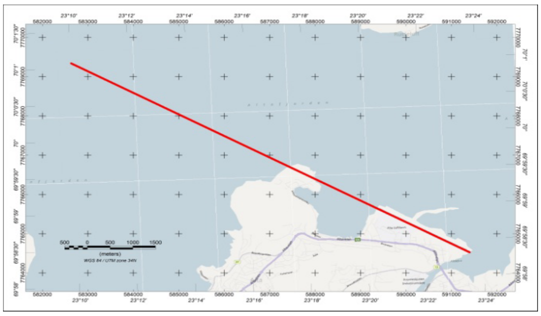
This test is performed over an easily recognised point on the ground. The purpose is to ensure that aeromagnetic survey system measures the total field values with an absolute accuracy of 10nT or less after the aircraft has been compensated. The result from the test together with the FOM is also used to remove aircraft influence on magnetic data (heading error).

Analysis of the synchronisation tests and noise level of the magnetometers, chapter A and B of the present report, compile for each aircraft and all the test lines, shows clearly that both aircrafts have an absolute difference of less than 10nT.

Since the compensation also corrects the heading error, there is no need for an extra calibration on C-GJDD.

E. Test line and QC tests

FRAS WEST



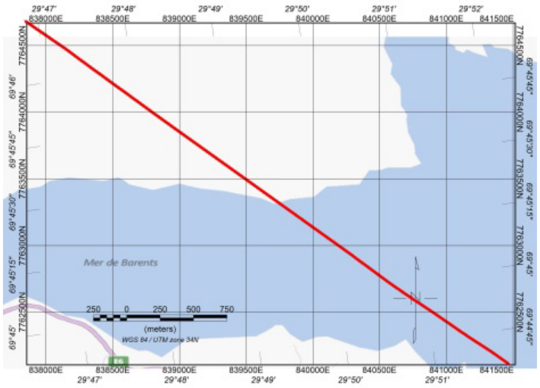
Date: 2011.06 – 2011.08

Location: Alta airport, NORWAY

Instrument: Spectrometer, RSI RSX500, 50.16L down, 12.54L up, **2Hz**

Flying Heights: 60m

FRAS EAST



Date: 2012.06 – 2012.10

Location: Kirkenesairport, NORWAY

Instrument: Spectrometer, RSI RSX500, 50.16L down, 12.54L up, **2Hz**

Flying Heights: 60m

During the survey, quality control is carried out by the project manager on site. Controls on the quality are integrated in the normal process of acquisition and start as soon as the flight path is established and end at the delivery of the final products.

A survey test lines will be flown at the beginning of each flight as a check on system sensitivity, the stability of the magnetometers and spectrometers, and finally to monitor the effect of soil moisture in the area, (Variation of thorium concentration less than 10% after corrections on every flight).

Results will be presented in the Weekly Report as mean values difference over the average value measured within the duration of the project. The extension of the test line is about 10 km. The measurement over the water will be used for the calibration of the gamma ray upward looking detector.

After each flight, the raw data are inspected to make sure that there are no missing data or corrupted data. Data are then saved on an independent and secure location. For each flight, the following controls are then carried out in priority, to ensure:

- The deviations on both sides of the flight lines (±50m over 5000m)
- The altitude deviations of the flight lines (60m above the drape surface over 3000m)
- Spacing between each measurement (225 km/h ± 25 km/h over 5000m)
- The diurnal drifts (100 nT/h, 35 nT/10min, 15 nT/2min)
- The noise level of the data (Mean 4^{th} difference over 4000m less than 1.6)

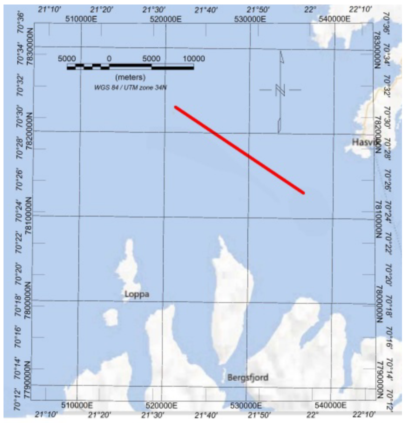
Quality control maps are then issued in the Weekly Report and sent to the NGU representative every weekend of the project duration.

Finally, the following radiometric checks are performed every morning to ensure spectra constancy and are included in the Weekly Report:

- Stabilisation better than ±25 keV measured on the 2.62 MeV ^{208}Tl peak
- FWHM better than 200 keV measured on the 2.62 MeV ^{208}Tl peak

- Careful verification of each profile (and spectra) to spot spikes, jumps or interruptions in the readings
- Statistical calculation of the mean spectra for each line to insure potassium and thorium peak stability (drift less than 4 channels on the thorium peak)
- Correction and gridding of preliminary grids to evaluate data coherence and consistency.

F. Cosmic and Aircraft Background Correction



Date: 2012.10.02

Location: North West of Alta, Norwegian Sea, NORWAY

Aircraft: PA31 **C-GJDD**

Instrument: Spectrometer, RSI RSX500, 50.16L down, 12.54L up, **2Hz**

Temperature: 9.8°C at sea level
Pressure: 100.5 kPa at sea level

Height: 1500-3000 m

To determine the cosmic and aircraft background, the spectrometer used records all incident particles above 3 MeV in the Cosmic channel. Steps are flown at 7 equidistant heights, from 1500m to 3000m and over the sea to reduce the presence of radon. Furthermore, in order to minimize statistical errors, each step is 18 km long and lasts around 8 minutes.

It was established that radon contamination is notably apparent and result in a breakdown of the linear relationship. Mean counts and linear relations of the cosmic radiations in the various spectral windows are represented below. The lower flight was then rejected.

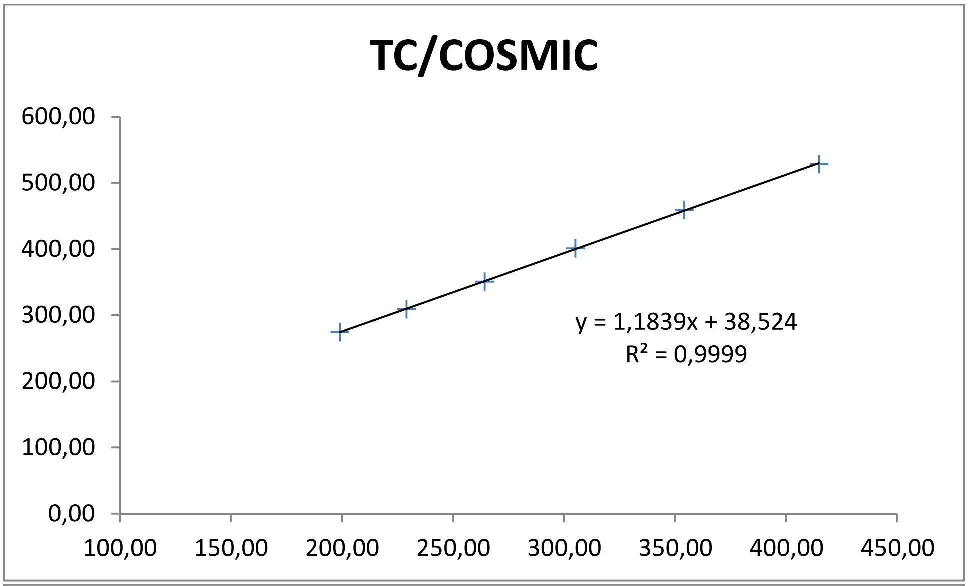
Altimeter (m)	Cosmic Dn	Cosmic Up	Total Count	Potassium	Uranium	Thorium	Up Uranium
3000,13	414,69	111,29	528,24	35,04	24,18	27,18	6,05
2700,31	354,00	95,64	459,08	31,13	20,40	23,25	5,19
2399,92	305,03	81,83	400,58	27,89	17,70	19,92	4,41
2099,26	264,09	72,14	350,51	24,96	15,72	17,10	4,04
1799,86	228,93	61,59	308,91	23,01	13,37	14,84	3,29
1499,09	199,01	54,03	274,25	20,42	12,09	12,90	2,93

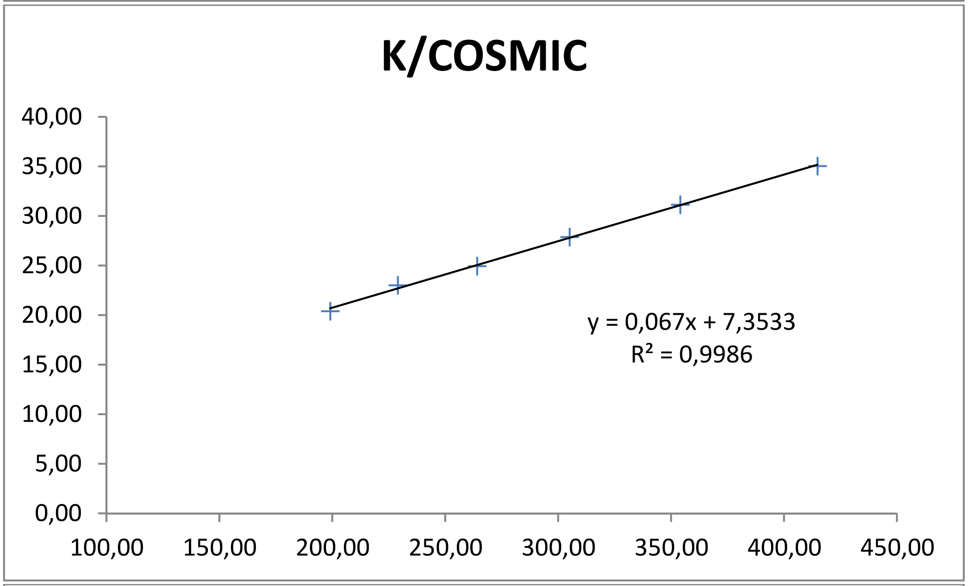
Table 11 : Steps averaged data (Aircraft GJDD)

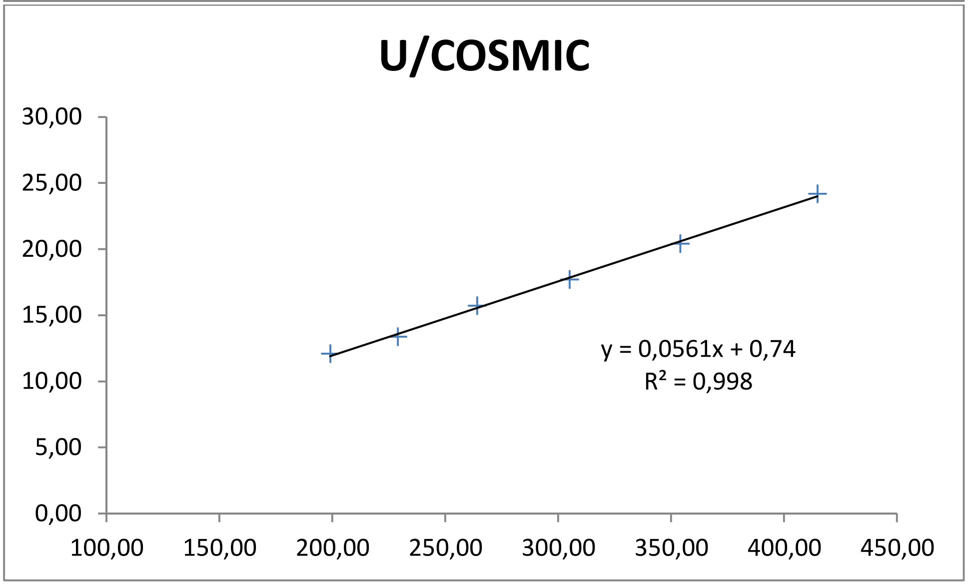
Background	Total Count	Potassium	Uranium	Thorium	Up Uranium
Aircraft	38.5	7.35	0.056	0.067	0.055
Cosmic	1.184	0.067	0.74	-0.39	-0.01

Table 12 : Cosmic & Aircraft background coefficients (Aircraft GJDD)

Notice that the coefficient of determination is remarkably high for every window. Lower coefficients would have been characteristic of the radon concentration variation in the air during the flight as the thorium window is less affected and the uranium and total count are closely correlated. However, the only effect of varying radon during the cosmic-ray calibration flights will be an unknown radon component which will be removed during radon processing, as it is demonstrated in *Grasty and Minty, AGSO 1995/60*.


TC/COSMIC
600,00
500,00
400,00
300,00
200,00
100,00
0,00
100,00
150,00
200,00
250,00
300,00
350,00
400,00
450,00
y = 1,1839x + 38,524
R² = 0,9999


K/COSMIC
40,00
35,00
30,00
25,00
20,00
15,00
10,00
5,00
0,00
100,00
150,00
200,00
250,00
300,00
350,00
400,00
450,00
y = 0,067x + 7,3533
R² = 0,9986


U/COSMIC
30,00
25,00
20,00
15,00
10,00
5,00
0,00
100,00
150,00
200,00
250,00
300,00
350,00
400,00
450,00
y = 0,0561x + 0,74
R² = 0,998

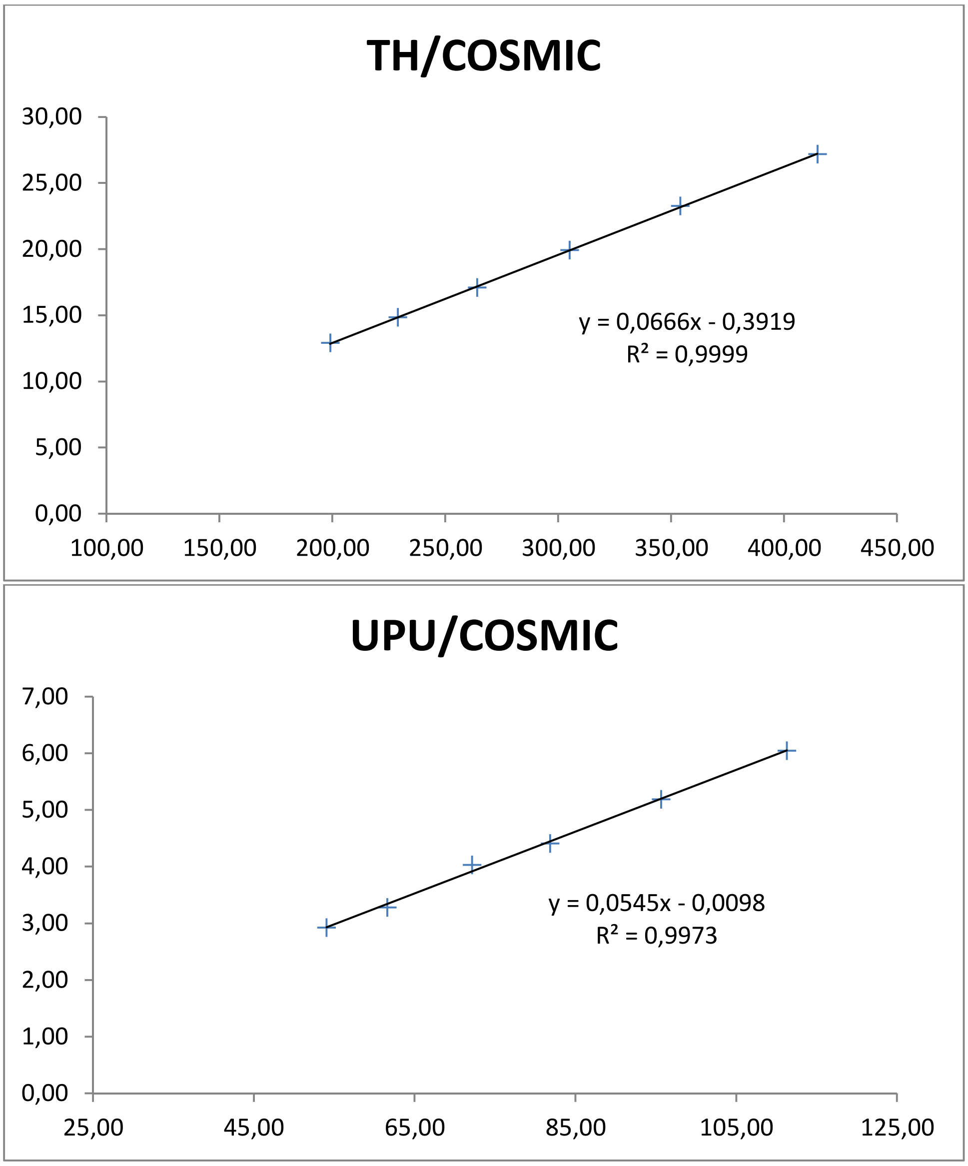


Figure 10 : Background correction

G. UPWARD LOOKING DETECTOR CORRECTION COEFFICIENTS

Location: Coast line Western NORWAY, 2011 - 2012

Aircraft: PA31 **C-GJDD**

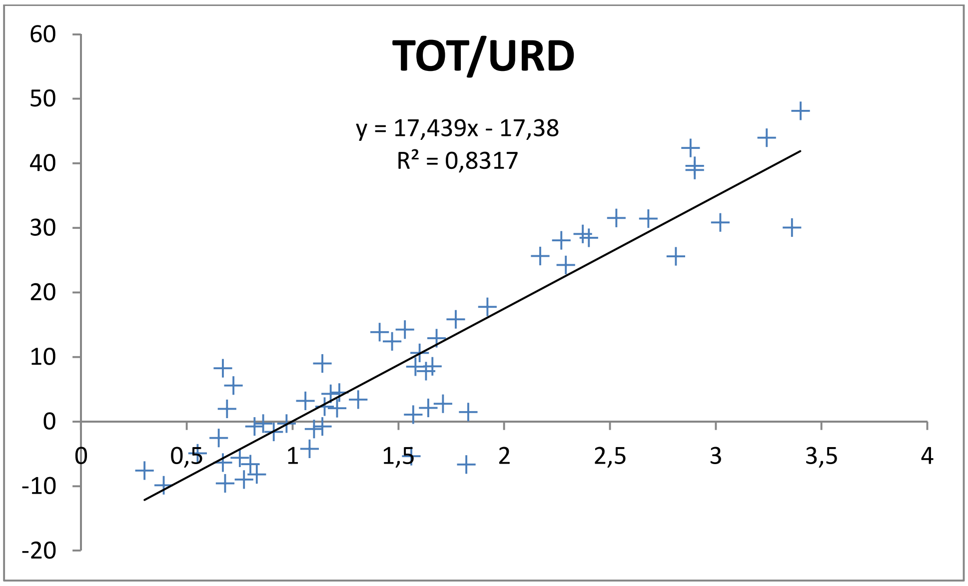
Instrument: Spectrometer, RSI RSX500, 50.16L down, 12.54L up, **2Hz**

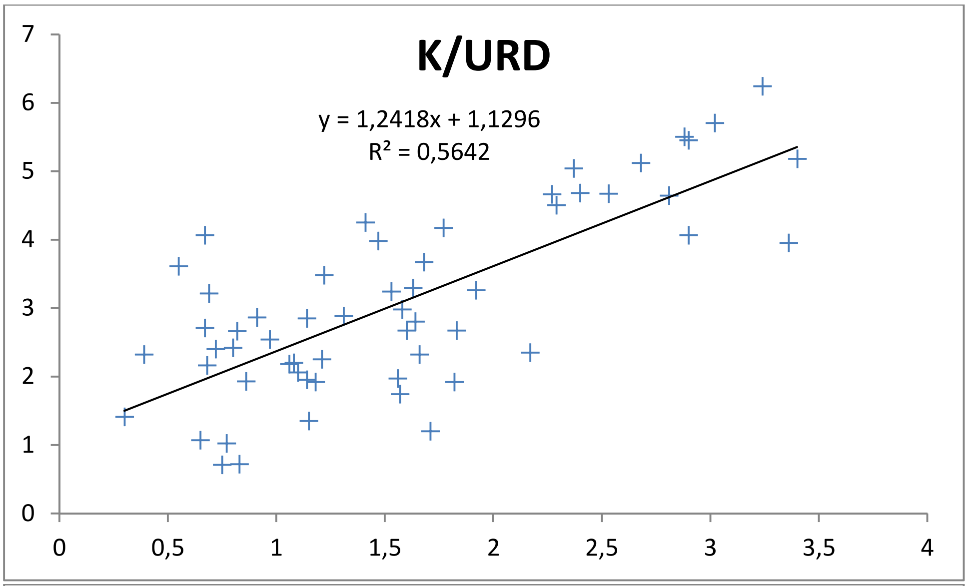
Flying Height: 60 m

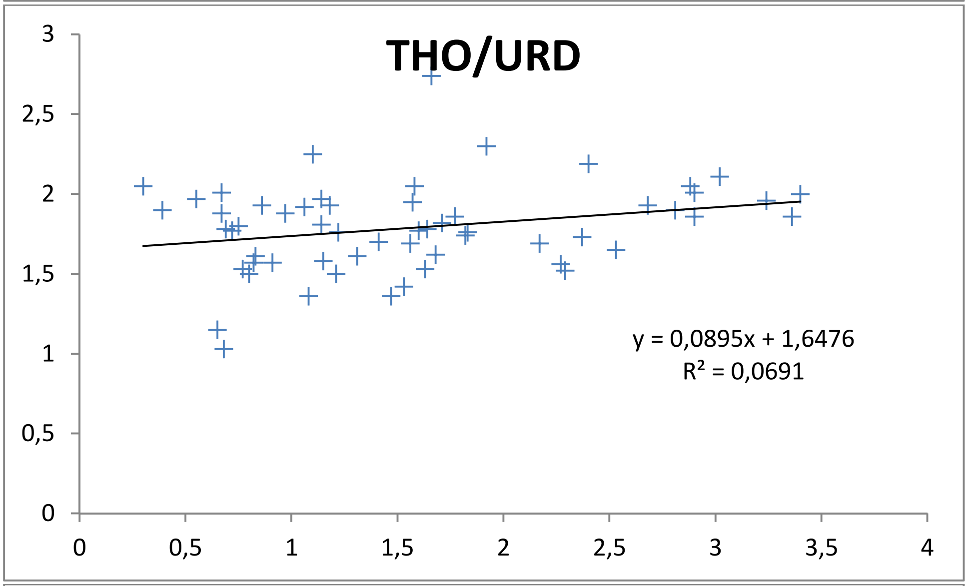
In order to determine the relationship between the upward and downward detector count rates for radon in the air, series of flights over water, where there is no contribution from the ground, will be done as a part of the test line.

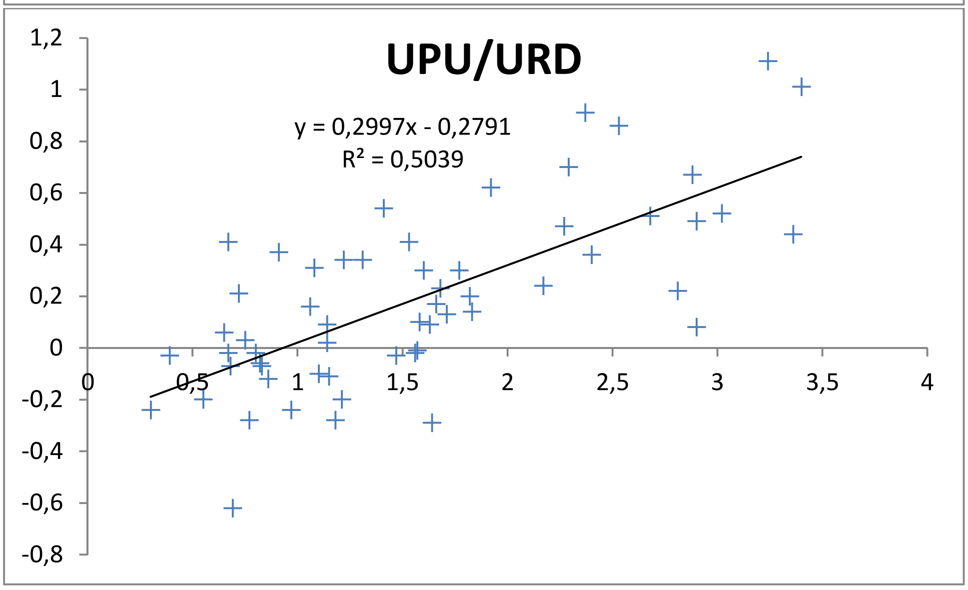
Prior to the analysis, aircraft background and cosmic component are removed and the dead time correction done. Since the cosmic and aircraft background calibration test leaded to highly reliable results, shown by the coefficients of determination R_2 in each window, we expect linear constants b_n to be close to zero. In addition, in order to minimize the statistical noise, only series over 20 valid counts are used. The results are presented in the following graphs.

Coefficients determined can have sometime a negative value. That can be explained by a variation of radon concentration during the calibration of the cosmic radiation. This unknown radon component is precisely removed by considering the given residual components at the time of the radon correction; results described in Grasty and Minty, AGSO 1995/60.




K/URD
y = 1,2418x + 1,1296
R² = 0,5642
0
1
2
3
4
5
6
7
0
0,5
1
1,5
2
2,5
3
3,5
4


THO/URD
y = 0,0895x + 1,6476
R² = 0,0691
0
0,5
1
1,5
2
2,5
3
0
0,5
1
1,5
2
2,5
3
3,5
4


UPU/URD
y = 0,2997x - 0,2791
R² = 0,5039
-0,8
-0,6
-0,4
-0,2
0
0,2
0,4
0,6
0,8
1
1,2
0
0,5
1
1,5
2
2,5
3
3,5
4

The constants above water for the four windows are:

$$a_u, b_u = 0.297, 0.03$$
$$a_K, b_K = 0.846, 0.93$$
$$a_{Th}, b_{Th} = 0.019, 0.31$$
$$a_{TC}, b_{TC} = 15.64, 9.45$$

The component of the upward detector count rate originating from the ground, u_g, will depend on the concentration of U an Th in the ground, as will the components of U and Th downward window count rates, U_g and Th_g, that originate from the ground. In order to minimize the statistical errors, the three components were calculated by subtracting flights above water present on Stad at the values adjacent on the firm ground. Numerous sites have thus been evaluated on the block. Finally, from the series of calculated values of U_g, U_g and Th_g, the calibration factors, a_1 and a_2, are determined by the least squares method described in IAEA Technical reports series No.323.

a_1	a_2
0.030	0.030

H. PADS CALIBRATION

RADIATION SOLUTIONS INC

CALIBRATION SHEET

Instrument: **RSX-5**

Customer: Novatem
Contact: Jeremie Largeaud
Console : N/A
Detector 1: 5523
Detector 2: N/A

Date: July 20, 2011
Tech.: GP
Job Order: SO#9734
Customer PO PO#

Channels: 1024 **ADC Offset:** N/A

	A1	A2	A3	A4	A5
High Voltages	714	705	725	704	693

Stripping Constant	"this system"	"normal"
Alpha	**0.288**	0.250
Beta	**0.404**	0.400
Gamma	**0.775**	0.810
a	**0.051**	0.060
b	**0.003**	0.000
g	**0.002**	0.003

ROI#	Channel	IAEA Specification [keV]	Label
1	137-937	410-2810	Total Count
2	457-523	1370-1570	Potassium K
3	553-620	1660-1860	Uranium U
4	803-937	2410-2810	Thorium Th
5			
6			
7			
8	553-620	1660-1860	Uranium Upper U

Det#	Peak Cs	Cs FWHM	Peak Th	Th FWHM
A1	220.84	8.37	872.30	4.91
A2	220.76	8.66	872.35	5.46
A3	221.26	8.45	872.12	5.22
A4	220.89	7.82	871.95	4.55
Sum Dn	**220.94**	**8.30**	**872.10**	**5.06**
Sum Up	**221.19**	**9.70**	**871.12**	**6.56**

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RADIATION SOLUTIONS INC

CALIBRATION SHEET

Instrument: **RSX-5**

Customer:	Novatem	Date:	May 25, 2012
Contact:		Tech.:	GP
Console :	N/A	Job Order:	SO#2166
Detector 1:	5629	Customer PO	PO#103040
Detector 2:	N/A		

Channels: 1024 **ADC Offset:** N/A

	A1	A2	A3	A4	A5
High Voltages	642	661	642	619	733

Stripping Constant	"this system"	"normal"
Alpha	**0.274**	0.250
Beta	**0.400**	0.400
Gamma	**0.765**	0.810
a	**0.053**	0.060
b	**0.002**	0.000
g	**0.001**	0.003

ROI#	Channel	IAEA Specification [keV]	Label
1	137-937	410-2810	Total Count
2	457-523	1370-1570	Potassium K
3	553-620	1660-1860	Uranium U
4	803-937	2410-2810	Thorium Th
5			
6			
7			
8	553-620	1660-1860	Uranium Upper U

Det#	Peak Cs	Cs FWHM		Peak Th	Th FWHM
A1	220.13	7.46		872.90	4.54
A2	220.07	7.41		871.99	4.28
A3	219.77	7.45		872.98	4.53
A4	220.37	7.29		872.79	4.25
Sum Dn	**220.08**	**7.40**		**872.65**	**4.39**
Sum Up	**220.37**	**7.94**		**872.23**	**4.94**

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RADIATION SOLUTIONS INC

CALIBRATION SHEET

Instrument: **RSX-5**

Customer:	Novatem	Date:	May 25, 2012
Contact:		Tech.:	GP
Console :	N/A	Job Order:	SO#2166
Detector 1:	5630	Customer PO	PO#103040
Detector 2:	N/A		

Channels: 1024 **ADC Offset:** N/A

	A1	A2	A3	A4	A5
High Voltages	633	635	635	645	640

Stripping Constant	"this system"	"normal"
Alpha	**0.275**	0.250
Beta	**0.404**	0.400
Gamma	**0.753**	0.810
a	**0.047**	0.060
b	**-0.001**	0.000
g	**0.000**	0.003

ROI#	Channel	IAEA Specification [keV]	Label
1	137-937	410-2810	Total Count
2	457-523	1370-1570	Potassium K
3	553-620	1660-1860	Uranium U
4	803-937	2410-2810	Thorium Th
5			
6			
7			
8	553-620	1660-1860	Uranium Upper U

Det#	Peak Cs	Cs FWHM		Peak Th	Th FWHM
A1	220.21	7.28		872.96	4.16
A2	220.28	7.48		872.58	4.45
A3	220.14	7.49		871.85	4.65
A4	219.72	7.31		872.74	4.23
Sum Dn	**220.07**	**7.39**		**872.57**	**4.35**
Sum Up	**220.79**	**7.73**		**872.33**	**4.68**

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I. HEIGHT ATTENUATION & SENSITIVITY

Date: 2011.06.06

Location: Breckenridge, Quebec, CANADA

Aircraft: PA31 **C-GJDD**

Instruments: Spectrometer, RSI RSX500, 50.16L down, 12.54L up, **2Hz**
5510, 5523
Geological Survey of Canada, Portable spectrometer for ground measurements

Test Area: TC=54.94 nGy/h, K= 1.96%, eU= 1.55ppm, eTh= 8.20ppm

Temperature: 20°C at sea level

Pressure: 100.2 kPa at sea level

Height: 50-230m

STP Corrected	Total Count	Potassium	Uranium	Thorium
36,82	1928,46	218,91	44,04	65,04
56,76	1680,55	185,14	39,31	56,48
82,91	1420,19	148,23	35,11	46,79
111,15	1206,24	120,63	30,56	39,31

Table 13 : Test Data (cps)

STP Corrected	Total Count	Potassium	Uranium	Thorium
36,82	202,4	13,75	9,5	7,1
56,76	209,88	14,74	10,35	6,9
82,91	218,01	14,7	10,51	7,02
111,15	225,43	15,58	10,84	7,21

Table 14 : Background Data (cps)

α	β	γ	a	b	g
0,297	0,427	0,789	0,050	0,001	0,001

Table 15 : Stripping ratios

Total Count	Potassium	Uranium	Thorium
1726,06	175,16	17,92	58,36
1470,67	144,80	14,22	50,01
1202,18	111,76	12,32	40,09
980,81	87,35	9,35	32,40

Table 16 : Background-Corrected & Stripped Counts (cps))

After dead time correction, mean count rates of all four windows are then corrected from the cosmic radiation, atmospheric radioactivity and aircraft background by subtracting adjacent values over water. STP corrected Compton stripping ratios are then applied to the count rates. The stripped count rates at each altitude are finally fitted to the exponential function to give the height attenuation coefficients. The following figure shows the curves for all four windows, determined from the test strip.

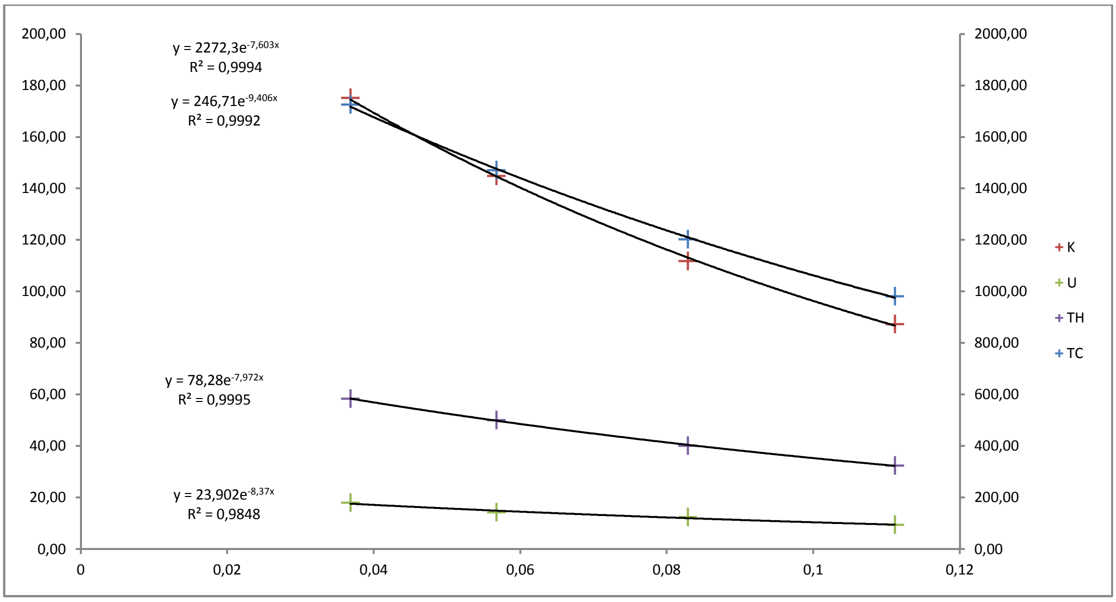


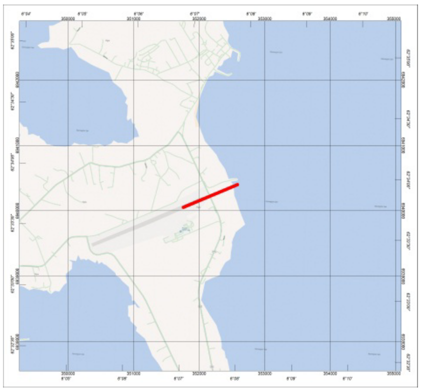
Figure 11 : Exponential height attenuation for all four windows

Broad source sensitivity for each window was calculated using concentration of the radioelement measured at ground level on the strip and for a final STP height of 60m. All the results are shown in the following table.

	Total Count	Potassium	Uranium	Thorium
ATTENUATION	-0.00760 m^{-1}	-0.00941 m^{-1}	-0.00837 m^{-1}	-0.00797 m^{-1}
SENSITIVITY	26,21 cps/ nGy/h	71,51 cps/%	9,31cps/ppm	5,92 cps/ppm

Table 17 : Attenuation coefficients & Sensitivity (60m)

J. LAG TEST



Date: 2012.02.15

Location: Flyplasstunnelen, Fv137
Vigra Airport, NORWAY

Aircraft: PA31 **C-GJDD**

Instrument: Magnetometers: G-823 Cesium magnetometer, **10Hz**

Heights: 60 m

Taking into account the spatial difference between the GPS antenna and the different magnetometers, the following results show that there is almost no time lag in the data records. Note that the spatial lag will be taking into account in the processing in order to replace each magnetometer in the space for gradient enhancement.

MAG 1 (Left wing tip pod)

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L1:0	70	223.40	60.67	150022.5	352157.6	6940221.2	61.4	51689.810
L2:0	250	176.60	61.40	150230.8	352156.3	6940221.6	62.8	51676.240

MEAN SPEED = 62.1 m/s
DISTANCE = 1.322 m
LAG = 0.011 sec

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L3:0	70	210.70	63.36	150517.3	352157.1	6940217.2	61.4	51674.050
L4:0	250	176.80	67.47	150723.5	352157.9	6940221.5	62.8	51634.440

MEAN SPEED = 62.1 m/s
DISTANCE = 4.368 m
LAG = 0.035 sec

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L5:0	70	212.70	65.61	150950.0	352159.1	6940216.8	63.3	51656.120
L6:0	250	172.30	64.98	151207.9	352155.1	6940221.4	60.6	51651.570

MEAN SPEED = 61.9 m/s
DISTANCE = 6.083 m
LAG = 0.049 sec

MAG 2 (Right wing tip pod)

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L1:0	70	223.40	60.67	150022.5	352157.6	6940221.2	61.4	51696.560
L2:0	250	176.60	61.40	150230.8	352156.3	6940221.6	62.8	51692.240

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MEAN SPEED = 62.1 m/s
DISTANCE = 1.322 m
LAG = 0.011 sec

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L3:0	70	210.70	63.36	150517.3	352157.1	6940217.2	61.4	51666.260
L4:0	250	176.80	67.47	150723.5	352157.9	6940221.5	62.8	51655.930

MEAN SPEED = 62.1 m/s
DISTANCE = 4.368 m
LAG = 0.035 sec

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L5:0	70	212.70	65.61	150950.0	352159.1	6940216.8	63.3	51649.860
L6:0	250	172.30	64.98	151207.9	352155.1	6940221.4	60.6	51665.630

MEAN SPEED = 61.9 m/s
DISTANCE = 6.083 m
LAG = 0.049 sec

MAG 3 (Tail boom)

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L1:0	70	223.30	60.82	150022.7	352168.9	6940225.9	61.4	51718.670
L2:0	250	176.60	61.36	150230.9	352150.5	6940219.2	62.8	51710.760

MEAN SPEED = 62.1 m/s
DISTANCE = 19.582 m
LAG = 0.158 sec

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L3:0	70	210.60	63.32	150517.5	352168.4	6940221.9	61.4	51696.240
L4:0	250	176.80	67.55	150723.7	352146.3	6940216.7	62.8	51670.020

MEAN SPEED = 62.1 m/s
DISTANCE = 22.772 m
LAG = 0.183 sec

LINE	HEADING (°)	YAW (°)	ALTITUDE (m)	TIME (HHMMSS)	X (m)	Y (m)	SPEED (m/s)	HIGH PASS FILTERED MAG (nT)
L5:0	70	212.80	65.54	150950.2	352170.7	6940221.7	63.3	51678.350
L6:0	250	172.30	64.93	151208.0	352149.5	6940219.1	60.8	51685.630

MEAN SPEED = 62.1 m/s
DISTANCE = 21.418 m
LAG = 0.172 sec

K. LASER AND RADAR CALIBRATION

Date: 2012.02.15

Location: Vigra airport (alt: 2.74 m), NORWAY

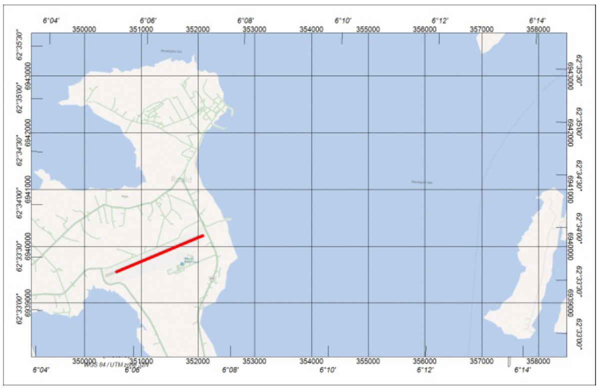
Aircraft: PA31 **C-GJDD**

Instrument: GPS receiver: Novatel Propak – V3, **10Hz**
Laser altimeter: Optech Sentinel 3100, **10Hz**
Radar altimeter: Free Flight TRA 4000, **10Hz**

Temperature: 9.0 °C at sea level

Pressure: 100.8 kPa at sea level

Heights: 40m-180m



To determine coefficients of calibration for the laser and radar altimeter, steps are flown at 5 different heights, from 40m to 180m and over the Alta airport strip in order to have a surface as flat as possible for the calibration. In order to minimize errors, each step is 2 km long.

The different altitudes recorded show a perfect linearity with the post processed GPS altitude. The airport altitude (2.75 m) was removed from the mean altitude recorded in order to evaluate the results. Finally, linear relations between the different altimeters are plotted below and calibration constants needed for processing are provided.

GPS altitude	Adjusted GPS altitude (m)	Laser altitude (m)	Radar altitude (m)
61.57	58.82	44.51	43.27
79.34	76.59	62.18	61.15
110.88	108.13	94.05	93.47
140.80	138.05	123.85	123.80
171.73	168.98	155.36	155.69
201.64	198.89	185.07	186.29

Table 18: Radar calibration

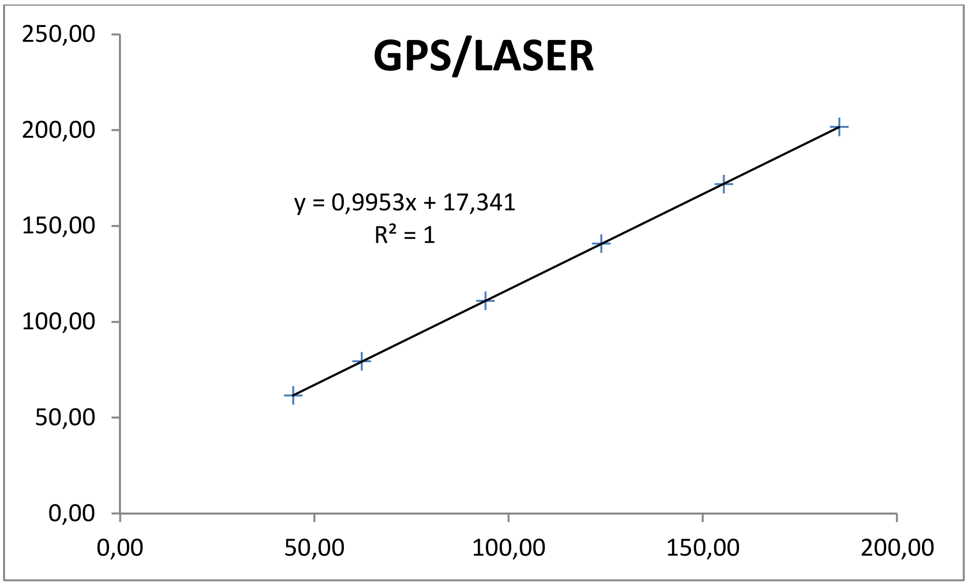


Figure 12 : Laser calibration

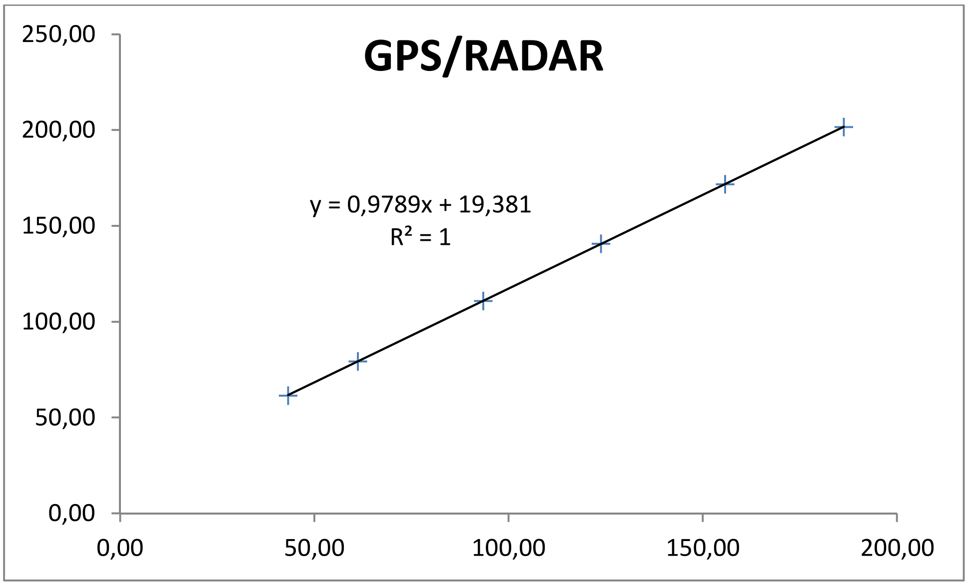


Figure 13 : Radar calibration