ABSOLUTE GRAVITY MEASUREMENTS IN THE CALIBRATION LABORATORY OF THE NEW HANGAR OF CARGOLUX

Final Report

November 18, 2009

Prof. Dr. Olivier Francis

University of Luxembourg
Faculty of Sciences, Technology and Communication
Campus Kirchberg
6, rue Coudenhove-Kalergi
L-1359 Luxembourg
Grand-Duché de Luxembourg

Tel. : +352 46 66 44 6264, Email : Olivier.francis@uni.lu

Foreword

This report contains the results of absolute gravity measurements carried out in the calibration laboratory of the new hangar of Cargolux (Figure 1) in June 2009. The absolute gravimeter FG5#216 from the European Center for Geodynamics and Seismology was operated by Olivier Francis and Gilbert Klein from the University of Luxembourg. The main objective of the measurement was to provide a reference point where the absolute value of gravity is known with an accuracy of a few microgal (1 microgal = 10 nm/s**2 is equivalent to 10^{-9} of g).

We would like to thank Yessine Meliani and Frank Cristophory from Cargolux for their warm hospitality and help during our measurements. The absolute gravity measurements were funded by the University of Luxembourg.
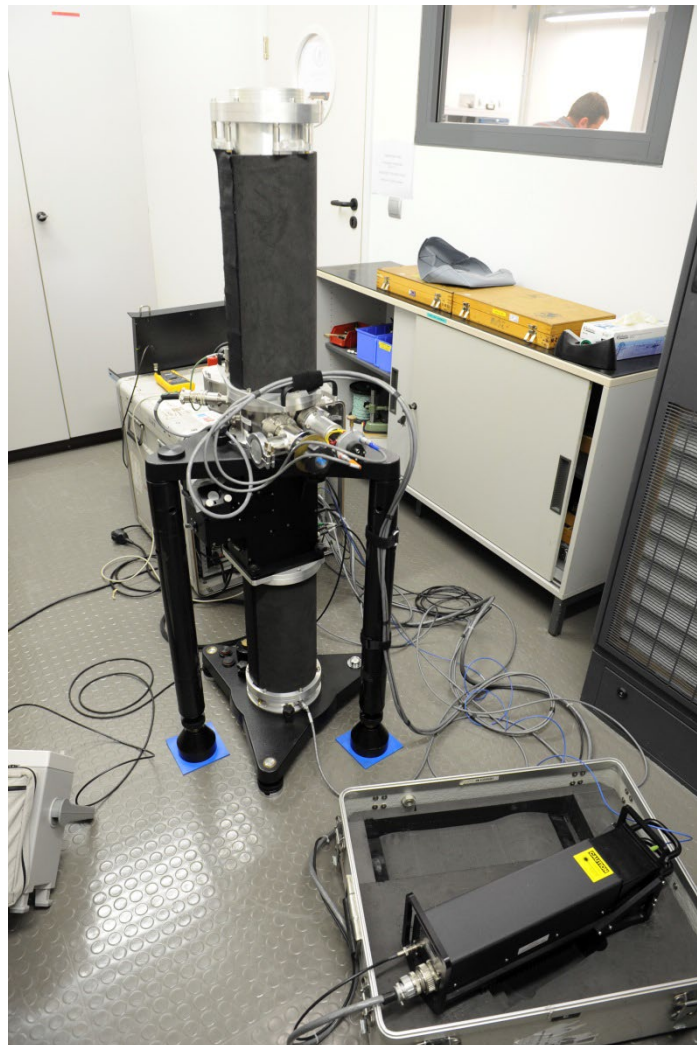

Figure 1. The absolute gravimeter FG5#216 in the calibration laboratory of Cargolux.

Data processing

Raw data from the absolute gravimeters consist of vectors of time and position of the falling object during the drops. To obtain the gravity value, a linear equation representing the equation of motion is fit to the raw data including the gravity gradient which as been measured with relative meters.

The data processing follows the protocol adopted during absolute gravimeters comparisons at the BIPM in Sèvres (Francis and van Dam, 2003). Geophysical corrections are applied to the raw gravity data: Earth tides using modelled tidal parameters, atmospheric pressure using a constant admittance, and the polar motion effect using pole positions from the International Earth Rotation Service (http://hpiers.obspm.fr).

The g-soft version 7.0 software from Microg-LaCoste Inc. was used for the processing. All the text outputs as well as some figures are compiled in the annexes of this report for future reference.

Vertical Gravity Gradient

The vertical gravity gradient is needed to linearize the equation of motion but also to transfer the measured absolute gravity value from the reference height around 1.3 m to the floor. Its determination requires relative measurements using a smaller and portable relative gravimeter. As we did not have the time to perform these measurements (and it could done in the near future), a standard value of –3.0 microGal/cm has been used to process the absolute gravity observations.

Results of the absolute gravity measurements

The FG5#216 operated from Tuesday 9th of June 2009 at 12:00 UTC until Wednesday 10th of June 2009 at 11:00 UTC. A total of 24 sets of 150 drops every 5 seconds were taken with a rate of 1 set per hour. It represents a total of 3600 drops. Sets 1 to 5 are excluded from the final data processing due to higher noise level due to the activities in the hangar. The best observations were taken during the night as expected as the human activities in the hangar slow down during that period. The absolute gravimeter is very sensitive to the floor vibrations.

Site	Gravity value /microGal	Uncertainty /microGal
Calibration Laboratory @ 1.3 m	980 949 782.49	1.69
Calibration Laboratory @ 0 m	980 650 171.07	15.09*

[*] 3.02 = Sqrt(1.69**2 + 15**2) where 15 microGal is the estimated error on the transfer from 1.3 m to the floor as the actual vertical gravity gradient has not been measured yet.

Reference

Francis O., van Dam T.M., Processing of the Absolute data of the ICAG01, Cahiers du Centre Européen de Géodynamique et de Séismologie, vol.22, 45-48, 2003. https://doi.org/10.5281/zenodo.7890604.

ANNEXES

STATION: CARGOLUX			
City:	Luxembourg	Country:	Luxembourg
Location:	Cargolux	Particularity:	
Situation:	Calibration Laboratory	Remarks:	
Date:	09-10 June 2009		

Code number:	
Latitude:	49.58397 degrees
Longitude:	6.19179 degrees
Elevation:	355.0 m
Gradient:	-3.0 µgal/cm
Reference height:	0. 1265 m + 1.1647 m = 1.2912m
Meter:	FG5
S/N:	216

Tidal corrections using observed tidal parameters

Polar motion correction			Air pressure correction	
X-coordinate	0.0644	Arc seconds	Nominal air pressure:	971.32 mbar
Y-coordinate	0.5405	Arc seconds	Barometric admittance factor:	0.3 µgal/mbar

Gravity

Set gravity mean:	**980 949 782.49**	microgal
Set std. dev.:	**1.69**	microgal
Mean std. dev.:	68.83	microgal
Number of sets:	19	
Number of drops per set:	150	
Drop interval:	5 seconds	
Set interval:	60 minutes	
Nominal/datum height:	1.30 m	
Author: O. Francis		University of Luxembourg

Date: November 18, 2009

Project file – ALL DATA

Micro-g Solutions g Processing Report
File Created: 11/17/09, 15:27:37

Project Name: CA20090609
g Acquisition Version: 1.082300
g Processing Version: 7.070307

Company/Institution: University of Luxembourg
Operator: Olivier Francis

Station Data
Name: CARGOLUX
Site Code: Calibration room
Lat: 49.58397 Long: 6.19179 Elev: 355.00 m
Setup Height: 12.65 cm
Transfer Height: 130.00 cm
Actual Height: 129.12 cm
Gradient: -3.000 µGal/cm
Nominal Air Pressure: 971.32 mBar
Barometric Admittance Factor: 0.30
Polar Motion Coord: 0.0644 " 0.5405 "
Earth Tide (ETGTAB) Selected
Potential Filename: C:\Program Files\Micro-g Solutions Inc\gWavefiles\Etcpot.dat
Delta Factor Filename: G:\ABSOLU\DATA\INI\walferdange.ini
Delta Factors

Start	Stop	Amplitude	Phase	Term
0.000000	0.002427	1.00000	0.0000	DC
0.002428	0.249951	1.16000	0.0000	LONG
0.721500	0.906315	1.14218	-1.4047	Q1
0.921941	0.940487	1.15001	0.1310	O1
0.958085	0.974188	1.16448	1.1522	M1
0.989049	1.011099	1.13628	0.3612	K1
1.013689	1.044800	1.17370	0.8380	J1
1.064841	1.216397	1.17638	4.7836	OO1
1.719381	1.872142	1.12839	3.3773	2N2
1.888387	1.906462	1.18419	3.5318	N2
1.923766	1.942754	1.19031	2.5519	M2
1.958233	1.976926	1.19620	2.7367	L2
1.991787	2.182843	1.19406	1.1885	S2
2.753244	3.081254	1.05599	0.0000	M3
3.791964	3.937897	1.05000	0.0000	M4

Instrument Data
Meter Type: FG5
Meter S/N: 216
Factory Height: 116.47 cm
Rubidium Frequency: 10000000.0100 Hz
Laser: WEO100 (187)
ID: 632.99117754 nm (0.89 V)
IE: 632.99119473 nm (0.40 V)
IF: 632.99121259 nm (0.07 V)
IG: 632.99123023 nm (-0.48 V)
IH: 632.99136890 nm (-1.27 V)
II: 632.99139822 nm (-1.19 V)
IJ: 632.99142704 nm (-1.15 V)
Modulation Frequency: 8333.420 Hz

Processing Results
Date: 06/09/09

Time: 23:36:14
DOY: 160
Year: 2009
Time Offset (D h:m:s): 0 0:0:0
Gravity: 980949783.10 µGal
Set Scatter: 3.89 µGal
Measurement Precision: 0.79 µGal
Total Uncertainty: 0.79 µGal
Number of Sets Collected: 24
Number of Sets Processed: 24
Set #s Processed: 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24
Number of Sets NOT Processed: 0
Set #s NOT Processed:
Number of Drops/Set: 150
Total Drops Accepted: 3523
Total Drops Rejected: 77
Total Fringes Acquired: 700
Fringe Start: 10
Processed Fringes: 610
GuideCard Multiplex: 4
GuideCard Scale Factor: 250

Acquisition Settings
Set Interval: 60 min
Drop Interval: 5 sec
Number of Sets: 24
Number of Drops: 150

Gravity Corrections
Earth Tide (ETGTAB): -14.31 µGal
Polar Motion: -0.11 µGal
Barometric Pressure: -0.67 µGal
Transfer Height: -2.64 µGal
Reference Xo: -0.00 µGal

Set File – All Data

Source Data Filename: CA20090609
g Acquisition Version: 1.082300
g Processing Version: 7.070307

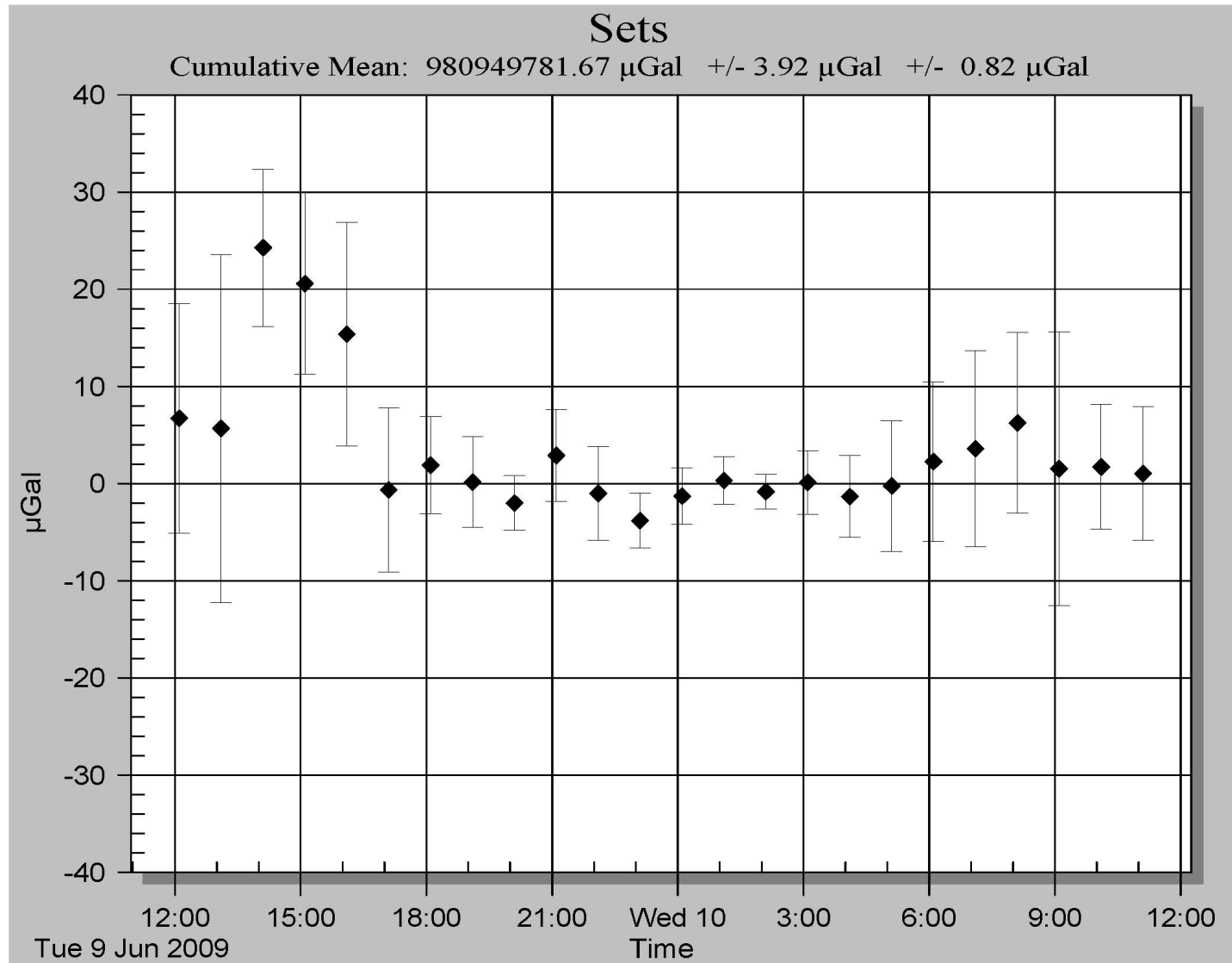| Set	Time	DOY	Year	Gravity	Sigma	Error	Uncert	Tide	Load	Baro	Polar	Transfer	Refxo	Temp	Pres	Accept	Reject
1	12:06:10	160	2009	980949788.401	143.375	11.825	11.825	117.422	0.000	-1.631	-0.108	-2.640	-0.002	24.658	965.884	147	3
2	13:06:12	160	2009	980949787.347	219.581	17.929	17.929	114.621	0.000	-1.764	-0.108	-2.640	-0.002	24.975	965.442	150	0
3	14:06:11	160	2009	980949805.970	98.808	8.095	8.095	96.480	0.000	-1.738	-0.108	-2.640	-0.002	24.522	965.526	149	1
4	15:06:15	160	2009	980949802.263	112.279	9.324	9.324	66.399	0.000	-1.616	-0.108	-2.640	-0.002	24.415	965.935	145	5
5	16:06:14	160	2009	980949797.071	140.197	11.524	11.524	29.908	0.000	-1.363	-0.108	-2.640	-0.002	24.697	966.777	148	2
6	17:06:16	160	2009	980949781.045	102.516	8.455	8.455	-6.864	0.000	-1.318	-0.108	-2.640	-0.002	25.406	966.927	147	3
7	18:06:12	160	2009	980949783.570	61.183	4.996	4.996	-38.214	0.000	-1.182	-0.108	-2.640	-0.002	25.553	967.379	150	0
8	19:06:20	160	2009	980949781.835	55.400	4.649	4.649	-60.406	0.000	-1.049	-0.108	-2.640	-0.002	25.568	967.823	142	8
9	20:06:13	160	2009	980949779.676	34.444	2.822	2.822	-71.932	0.000	-0.979	-0.108	-2.640	-0.002	25.548	968.056	149	1
10	21:06:12	160	2009	980949784.574	57.928	4.730	4.730	-74.072	0.000	-0.915	-0.108	-2.640	-0.002	25.557	968.268	150	0
11	22:06:11	160	2009	980949780.659	58.593	4.816	4.816	-69.994	0.000	-0.881	-0.108	-2.640	-0.002	25.523	968.382	148	2
12	23:06:10	160	2009	980949777.873	34.133	2.806	2.806	-63.853	0.000	-0.744	-0.108	-2.640	-0.002	25.447	968.841	148	2
13	00:06:13	161	2009	980949780.395	35.352	2.906	2.906	-59.497	0.000	-0.599	-0.108	-2.640	-0.002	25.484	969.324	148	2
14	01:06:21	161	2009	980949782.012	29.030	2.462	2.462	-59.333	0.000	-0.471	-0.108	-2.640	-0.002	25.447	969.751	139	11
15	02:06:08	161	2009	980949780.867	21.696	1.783	1.783	-63.556	0.000	-0.399	-0.108	-2.640	-0.002	25.484	969.990	148	2
16	03:06:12	161	2009	980949781.812	40.220	3.284	3.284	-70.184	0.000	-0.342	-0.108	-2.640	-0.002	25.481	970.180	150	0
17	04:06:23	161	2009	980949780.345	50.647	4.221	4.221	-75.540	0.000	-0.214	-0.108	-2.640	-0.002	25.488	970.608	144	6
18	05:06:14	161	2009	980949781.437	81.843	6.727	6.727	-75.405	0.000	-0.144	-0.108	-2.640	-0.002	25.250	970.840	148	2
19	06:06:09	161	2009	980949783.939	99.877	8.238	8.238	-66.396	0.000	-0.021	-0.108	-2.640	-0.002	25.140	971.251	147	3
20	07:06:10	161	2009	980949785.265	123.367	10.107	10.107	-46.931	0.000	0.177	-0.108	-2.640	-0.002	25.222	971.909	149	1
21	08:06:27	161	2009	980949787.925	110.373	9.295	9.295	-17.866	0.000	0.248	-0.108	-2.640	-0.002	25.223	972.145	141	9
22	09:06:09	161	2009	980949783.224	169.651	14.089	14.089	16.856	0.000	0.279	-0.108	-2.640	-0.002	25.209	972.251	145	5
23	10:06:10	161	2009	980949783.398	76.513	6.421	6.421	52.391	0.000	0.220	-0.108	-2.640	-0.002	25.153	972.053	142	8
24	11:06:12	161	2009	980949782.725	83.930	6.876	6.876	82.600	0.000	0.341	-0.108	-2.640	-0.002	25.101	972.458	149	1

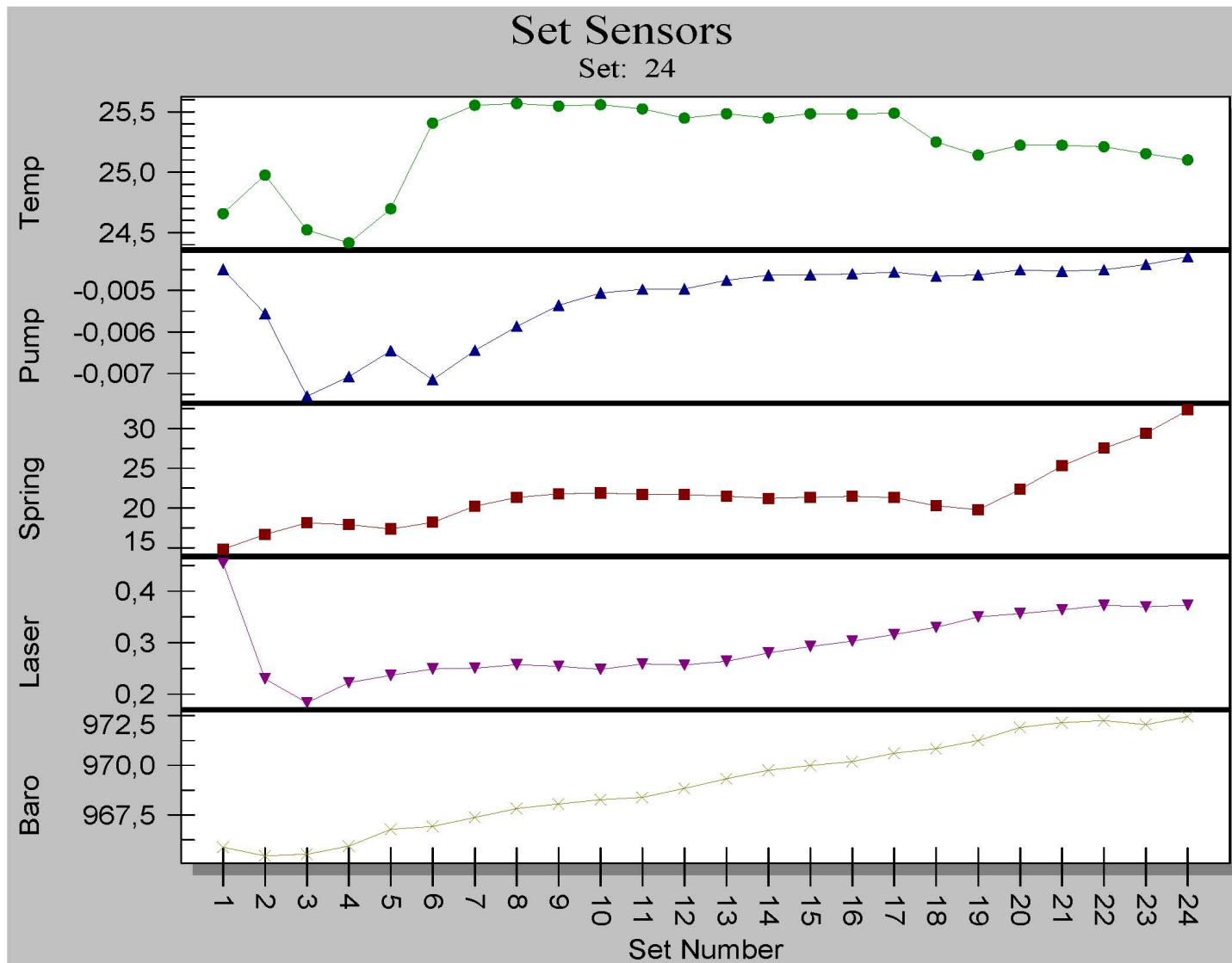**Figure 2.** Plot of the set gravity values (1 set = 100 drops).

Figure 3. Plot of the set sensor parameters (1 set = 100 drops).
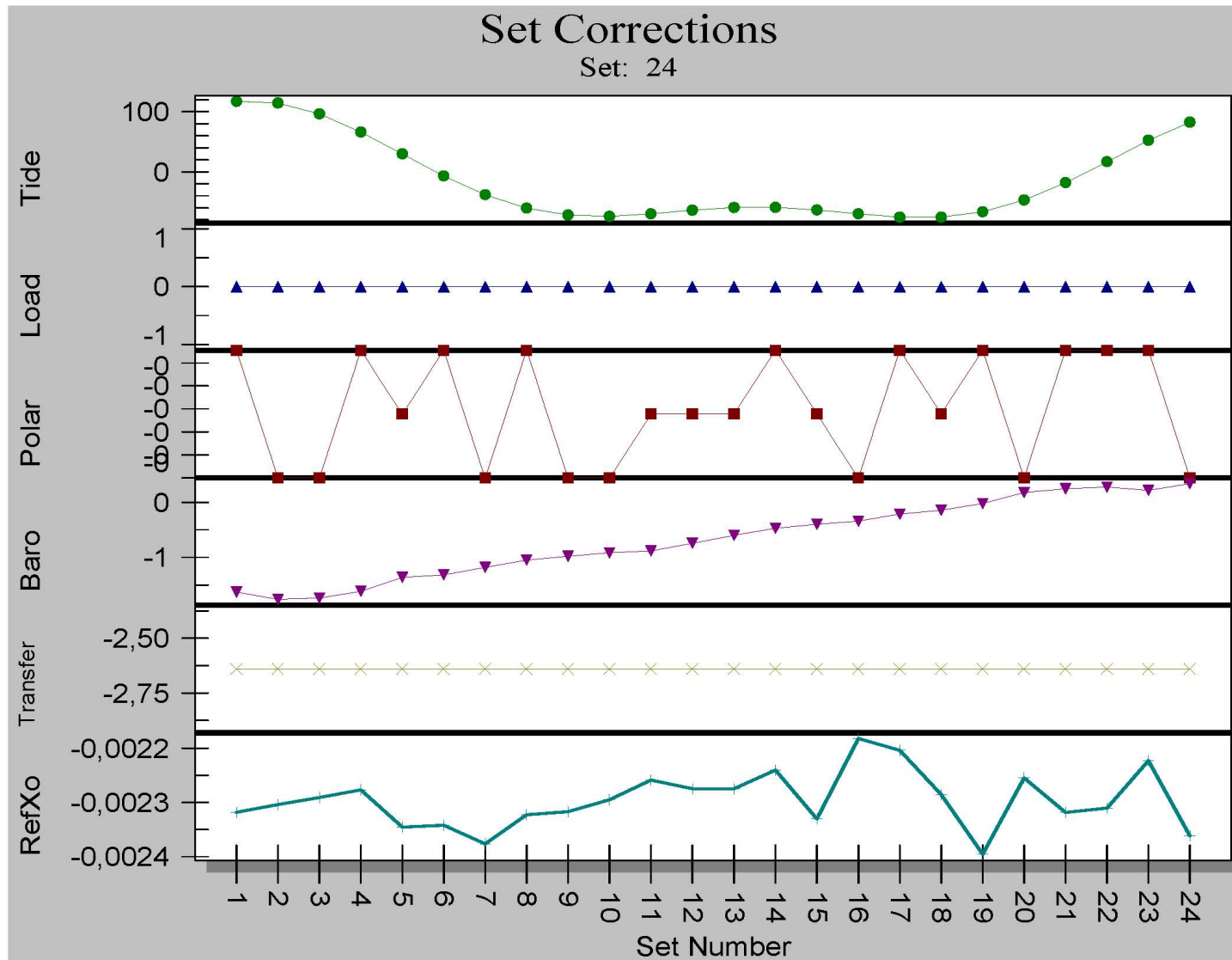
Figure 4. Plot of the set corrections values (1 set = 100 drops).

Project file – 5 first noisy sets removed

Micro-g Solutions g Processing Report
File Created: 11/17/09, 15:28:36

Project Name: CA20090609s
g Acquisition Version: 1.082300
g Processing Version: 7.070307

Company/Institution: University of Luxembourg
Operator: Olivier Francis

Station Data
Name: CARGOLUX
Site Code: Calibration room
Lat: 49.58397 Long: 6.19179 Elev: 355.00 m
Setup Height: 12.65 cm
Transfer Height: 130.00 cm
Actual Height: 129.12 cm
Gradient: -3.000 µGal/cm
Nominal Air Pressure: 971.32 mBar
Barometric Admittance Factor: 0.30
Polar Motion Coord: 0.0644 " 0.5405 "
Earth Tide (ETGTAB) Selected
Potential Filename: C:\Program Files\Micro-g Solutions Inc\gWavefiles\Etcpot.dat
Delta Factor Filename: G:\ABSOLU\DATA\INI\walferdange.ini
Delta Factors

Start	Stop	Amplitude	Phase	Term
0.000000	0.002427	1.00000	0.0000	DC
0.002428	0.249951	1.16000	0.0000	LONG
0.721500	0.906315	1.14218	-1.4047	Q1
0.921941	0.940487	1.15001	0.1310	O1
0.958085	0.974188	1.16448	1.1522	M1
0.989049	1.011099	1.13628	0.3612	K1
1.013689	1.044800	1.17370	0.8380	J1
1.064841	1.216397	1.17638	4.7836	OO1
1.719381	1.872142	1.12839	3.3773	2N2
1.888387	1.906462	1.18419	3.5318	N2
1.923766	1.942754	1.19031	2.5519	M2
1.958233	1.976926	1.19620	2.7367	L2
1.991787	2.182843	1.19406	1.1885	S2
2.753244	3.081254	1.05599	0.0000	M3
3.791964	3.937897	1.05000	0.0000	M4

Instrument Data
Meter Type: FG5
Meter S/N: 216
Factory Height: 116.47 cm
Rubidium Frequency: 10000000.0100 Hz
Laser: WEO100 (187)
ID: 632.99117754 nm (0.89 V)
IE: 632.99119473 nm (0.40 V)
IF: 632.99121259 nm (0.07 V)
IG: 632.99123023 nm (-0.48 V)
IH: 632.99136890 nm (-1.27 V)
II: 632.99139822 nm (-1.19 V)
IJ: 632.99142704 nm (-1.15 V)
Modulation Frequency: 8333.420 Hz

Processing Results
Date: 06/10/09
Time: 02:06:14
DOY: 161
Year: 2009
Time Offset (D h:m:s): 0 0:0:0
Gravity: 980949782.49 µGal
Set Scatter: 1.69 µGal
Measurement Precision: 0.39 µGal
Total Uncertainty: 0.39 µGal
Number of Sets Collected: 24
Number of Sets Processed: 19
Set #s Processed: 6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24
Number of Sets NOT Processed: 5
Set #s NOT Processed: 1,2,3,4,5
Number of Drops/Set: 150
Total Drops Accepted: 2784
Total Drops Rejected: 66
Total Fringes Acquired: 700
Fringe Start: 10
Processed Fringes: 610
GuideCard Multiplex: 4
GuideCard Scale Factor: 250

Acquisition Settings
Set Interval: 60 min
Drop Interval: 5 sec
Number of Sets: 24
Number of Drops: 150

Gravity Corrections
Earth Tide (ETGTAB): -40.43 µGal
Polar Motion: -0.11 µGal
Barometric Pressure: -0.42 µGal
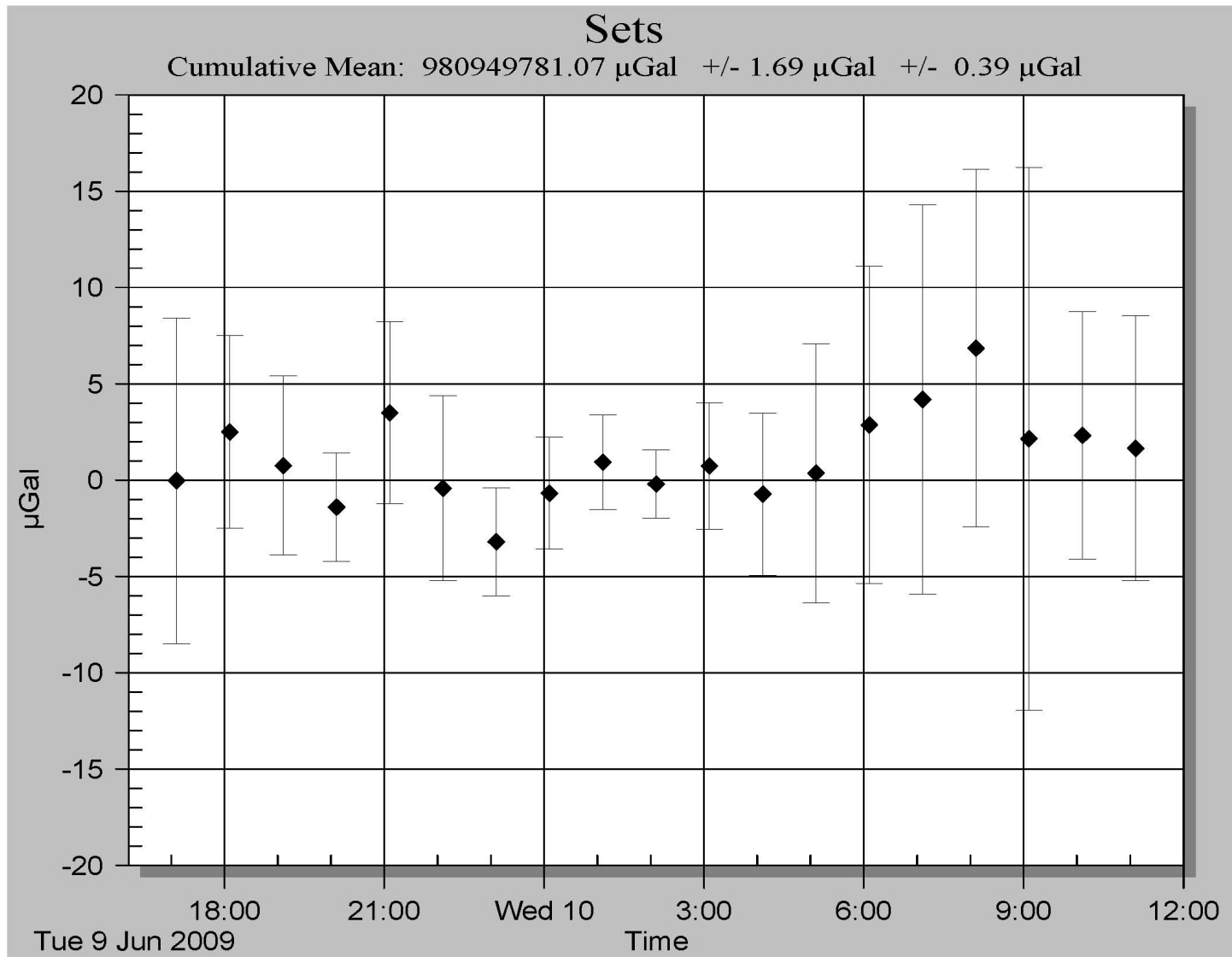Transfer Height: -2.64 µGal
Reference Xo: -0.00 µGal

.

Figure 5. Plot of the set gravity values (1 set = 100 drops) with the first five noisy sets removed.