

# **ABSOLUTE GRAVITY MEASUREMENTS IN THE MASS LABORATORY OF ILNAS IN CAPELLEN, LUXEMBOURG**

## **Final Report**

**June 2019**

Prof. Dr. Olivier Francis

*University of Luxembourg  
Maison du Nombre  
6, avenue de la Fonte  
L-4364 Esch-sur-Alzette*

*Tel. : +352 46 66 44 6264, Email : [Olivier.francis@uni.lu](mailto:Olivier.francis@uni.lu)*

## Foreword

This report contains the results of absolute gravity measurements carried out in the Mass Laboratory of ILNAS in Capellen, Luxembourg. The measurements took place on the floor tile next to the pillar where the mass comparators are installed. The absolute gravimeter FG5X#216 was operated by Olivier Francis from the Geophysics Laboratory of the University of Luxembourg which is also a Designated Institute (DI) for gravity by the Bureau Luxembourgeois de Métrologie (BLM).



**Figure 1.** Location of the absolute gravity measurements in the Mass Laboratory of ILNAS in Capellen.

## 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 that was measured with a relative gravimeter.

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 effect 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 v9.12.04.23 software from Microg-LaCoste Inc. is 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

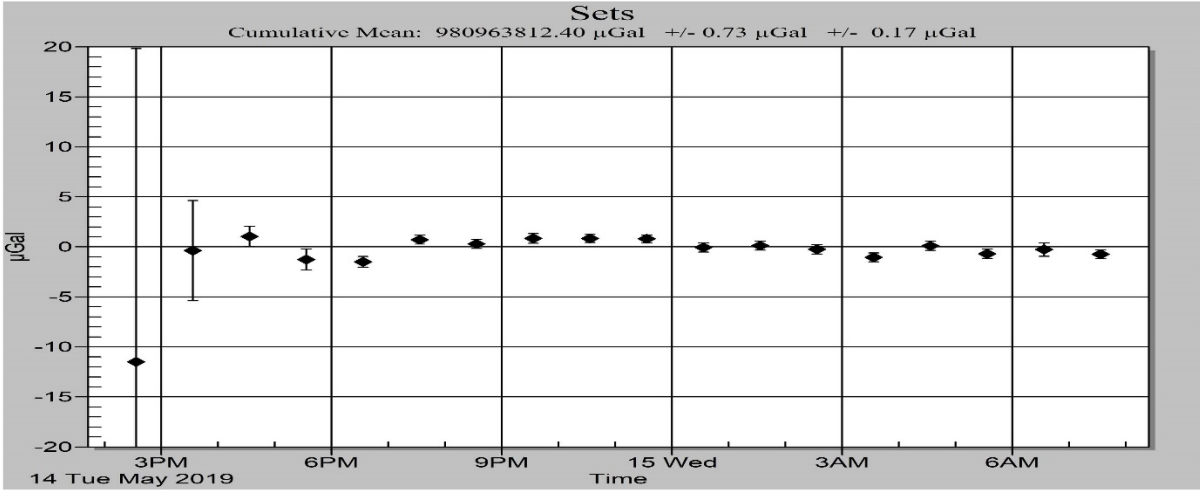
The vertical gravity gradient was measured with the relative spring gravimeter Scintrex CG6-003 from the University of Luxembourg. Relative measurements were performed at 3 different heights above the location of the absolute gravity measurements. The linear vertical gravity gradient is then calculated by fitting a straight line on the heights versus gravity differences plot. This gradient is needed to linearize the equation of motion but also to transfer the measured absolute gravity value from the reference height around 1.38 m to the floor. The values of the linear vertical gravity gradient is given in Table 1.

**Table 1.** Vertical gravity gradient measured at the absolute gravity location in the Mass Laboratory of IINAS in Capellen.

Station	Vertical Gravity gradient /microgal/cm	Standard Deviation /microgal/cm
CAPELLEN (ILNAS)	-3.029	0.006

## Results of the absolute gravity measurements

The FG5X#216 operated from Tuesday 14th of May 2019 at 14:25 UTC until Wednesday 15th of May 2019 at 07:42 UTC. A total of 18 sets of 200 drops every 5 seconds were taken with a rate of 1 set per hour. It represents a total of 3600 drops.



**Figure 2.** Set g-values: each dot is the average of 200 drops taken every 5 seconds. The error bar is the standard deviation within each individual sets.

The larger uncertainty of the two first data sets are due to an earthquake. These data were not removed as their contributions to the final result is close to zero. Indeed, to calculate the final g-value, a weighted average according to the RMS of each set is performed.

The final gravity g-value at the floor level is given in Table 2.

**Table 2.** Final result of the absolute gravity measurements in the Mass Laboratory of ILNAS in Capellen.

Site	Gravity value/ µGal	Mean Set Standard Deviation/ µGal
Mass Laboratory	980 963 812.40	0.73

## 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.

## ANNEXES

<b>STATION: Capellen – ILNAS – Laboratoire D’Essais – Mass Laboratory</b>			
City:	Capellen	Country:	Luxembourg
Location:	ILNAS Laboratoire d'Essais, 11a Rue de la Gare, L-8325 Capellen		
Situation:	Mass Laboratory	Remarks:	Tile floor
Date:	5-6 June 2018		
Code number:			
Latitude:	49.63935 degrees		
Longitude:	5.984444 degrees		
Elevation:	303.0 m		
Gradient:	-3.029 +/- 0.006 $\mu$ gal/cm		
Reference height:	0.1275 m + 1.2583 m = 1.3858 m		
Meter:	FG5X		
S/N:	216		
<b>Tidal corrections using observed tidal parameters</b>			
<b>Polar motion correction</b>			<b>Air pressure correction</b>
X-coordinate	0.0877	Arc seconds	Nominal air pressure: 978.31 mbar
Y-coordinate	0.4197	Arc seconds	Barometric admittance factor: 0.3 $\mu$ gal/mbar
<b>Gravity</b>			
Set gravity mean:	<b>980 963 812.40</b>	microgal	
Set std. dev.:	<b>0.73</b>	microgal	
Number of sets:	18		
Number of drops per set:	200		
Drop interval:	5seconds		
Set interval:	60 minutes		
Nominal/datum height:	0.00 m		
Author: O. Francis	University of Luxembourg		
Date: May 28, 2019			

# Project file

Micro-g LaCoste g Processing Report

File Created: 05/28/19, 10:50:58

Project Name: CA20190514

g Acquisition Version: 9.160516

g Processing Version: 9.120423

Company/Institution: University of Luxembourg

Operator: Olivier Francis

Station Data

Name: CAPELLEN

Site Code: ILNAS MASS LABORATORY

Lat: 49.63935 Long: 5.98444 Elev: 303.00 m

Setup Height: 12.75 cm

Transfer Height: 0.00 cm

Actual Height: 138.58 cm

Gradient: -3.029  $\mu$ Gal/cm

Nominal Air Pressure: 978.31 mBar

Barometric Admittance Factor: 0.30

Polar Motion Coord: 0.0877 " 0.4197 "

Earth Tide (ETGTAB) Selected

Potential Filename: C:\gData\gWavefiles\ETCPOT.dat

Delta Factor Filename: C:\gData\OceanLoad-CAPELLEN.dff

Delta Factors

Start	Stop	Amplitude	Phase Term
0.000000	0.000001	1.000000	0.0000 DC
0.000002	0.249951	1.160000	0.0000 Long
0.721500	0.906315	1.154250	0.0000 Q1
0.921941	0.974188	1.154240	0.0000 O1
0.989049	0.998028	1.149150	0.0000 P1
0.999853	1.216397	1.134890	0.0000 K1
1.719381	1.906462	1.161720	0.0000 N2
1.923766	1.976926	1.161720	0.0000 M2
1.991787	2.002885	1.161720	0.0000 S2
2.003032	2.182843	1.161720	0.0000 K2
2.753244	3.081254	1.07338	0.0000 M3
3.791964	3.937897	1.03900	0.0000 M4

Ocean Load ON, Filename: C:\gData\OceanLoad-CAPELLEN.olf

Waves: M2 S2 K1 O1 N2 P1 K2 Q1 Mf Mm Ssa

Amplitude ( $\mu$ Gal): 1.857 0.606 0.210 0.152 0.374 0.067 0.154 0.042 0.000 0.000 0.000

Phase (deg): 61.2 32.2 63.0 169.8 77.0 75.6 30.9 -126.0 0.0 0.0 0.0

Instrument Data

Meter Type: FG5

Meter S/N: X216

Factory Height: 125.83 cm

Rubidium Frequency: 10000000.00447 Hz

Laser: WEO100 (242)

ID: 632.99117754 nm ( 0.25 V)

IE: 632.99119473 nm (-0.25 V)

IF: 632.99121259 nm (-0.65 V)

IG: 632.99123023 nm (-1.03 V)

IH: 632.99136890 nm (-1.63 V)

II: 632.99139822 nm (-1.38 V)

IJ: 632.99142704 nm (-1.15 V)

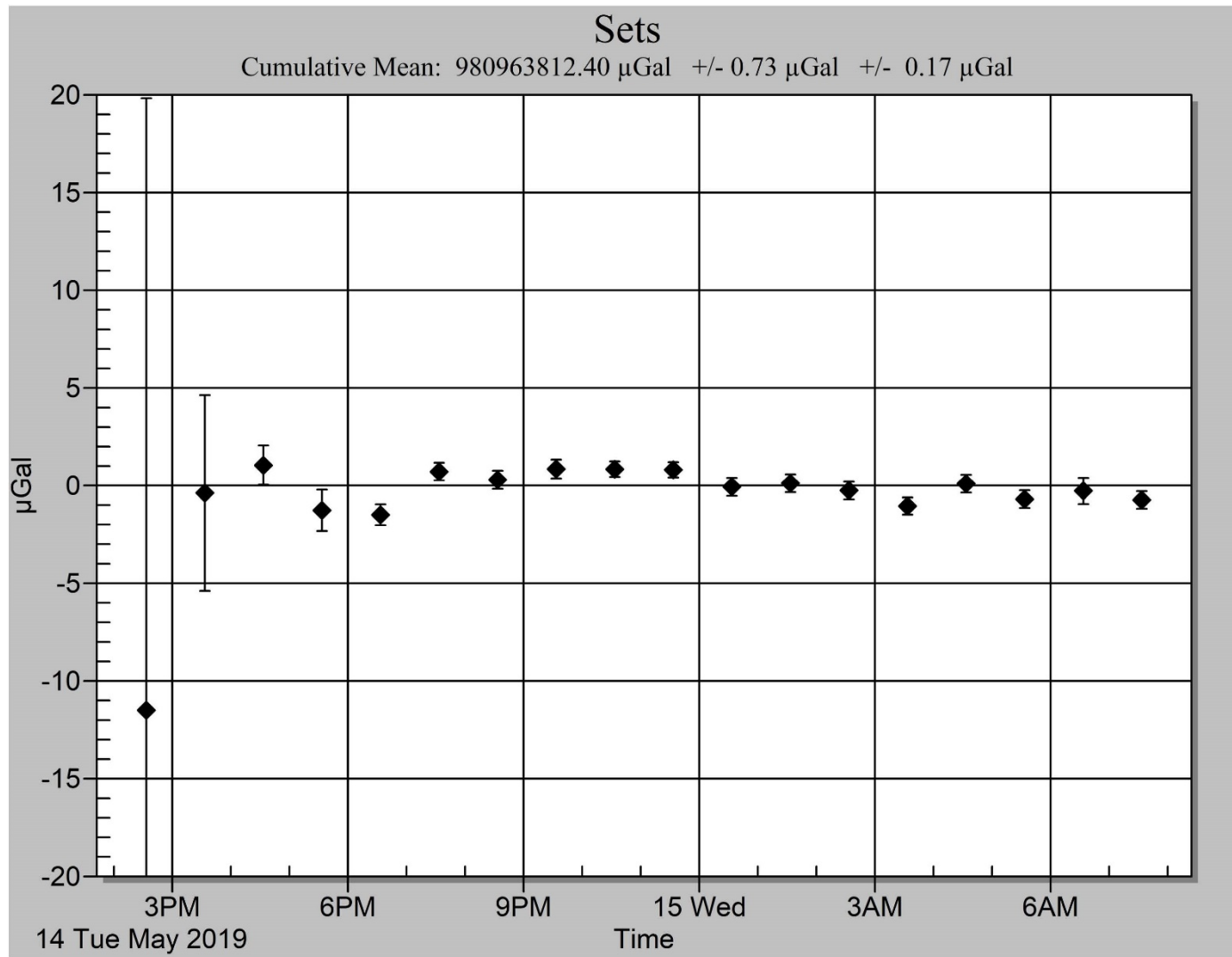
Modulation Frequency: 8333.350 Hz  
Processing Results  
Date: 05/14/19  
Time: 23:03:20  
DOY: 134  
Year: 2019  
Time Offset (D h:m:s): 0 0:0:0  
Gravity: 980963812.40  $\mu$ Gal  
Set Scatter: 0.73  $\mu$ Gal  
Measurement Precision: 0.17  $\mu$ Gal  
Total Uncertainty: 0.17  $\mu$ Gal  
Number of Sets Collected: 18  
Number of Sets Processed: 18  
Set #s Processed: 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18  
Number of Sets NOT Processed: 0  
Set #s NOT Processed:  
Number of Drops/Set: 200  
Total Drops Accepted: 3575  
Total Drops Rejected: 25  
Total Fringes Acquired: 1100  
Fringe Start: 2  
Processed Fringes: 1030  
GuideCard Multiplex: 4  
GuideCard Scale Factor: 250  
Acquisition Settings  
Set Interval: 60 min  
Drop Interval: 5 sec  
Number of Sets: 18  
Number of Drops: 200  
Gravity Corrections  
Earth Tide (ETGTAB): -37.34  $\mu$ Gal  
Ocean Load: 0.17  $\mu$ Gal  
Polar Motion: -0.82  $\mu$ Gal  
Barometric Pressure: 3.31  $\mu$ Gal  
Transfer Height: 419.76  $\mu$ Gal  
Reference Xo: 0.00  $\mu$ Gal  
Uncertainties  
Sigma Reject: 3.00  
Earth Tide Factor: 0.000  
Average Earth Tide Uncertainty: 0.00  $\mu$ Gal  
Ocean Load Factor: 0.00  
Average Ocean Load Uncertainty: 0.00  $\mu$ Gal  
Barometric: 0.00  $\mu$ Gal  
Polar Motion: 0.00  $\mu$ Gal  
Laser: 0.00  $\mu$ Gal  
Clock: 0.00  $\mu$ Gal  
System Type: 0.00  $\mu$ Gal  
Tidal Swell: 0.00  $\mu$ Gal  
Water Table: 0.00  $\mu$ Gal  
Unmodeled: 0.00  $\mu$ Gal  
System Setup: 0.00  $\mu$ Gal  
Gradient: 0.000  $\mu$ Gal (0.000  $\mu$ Gal/cm)



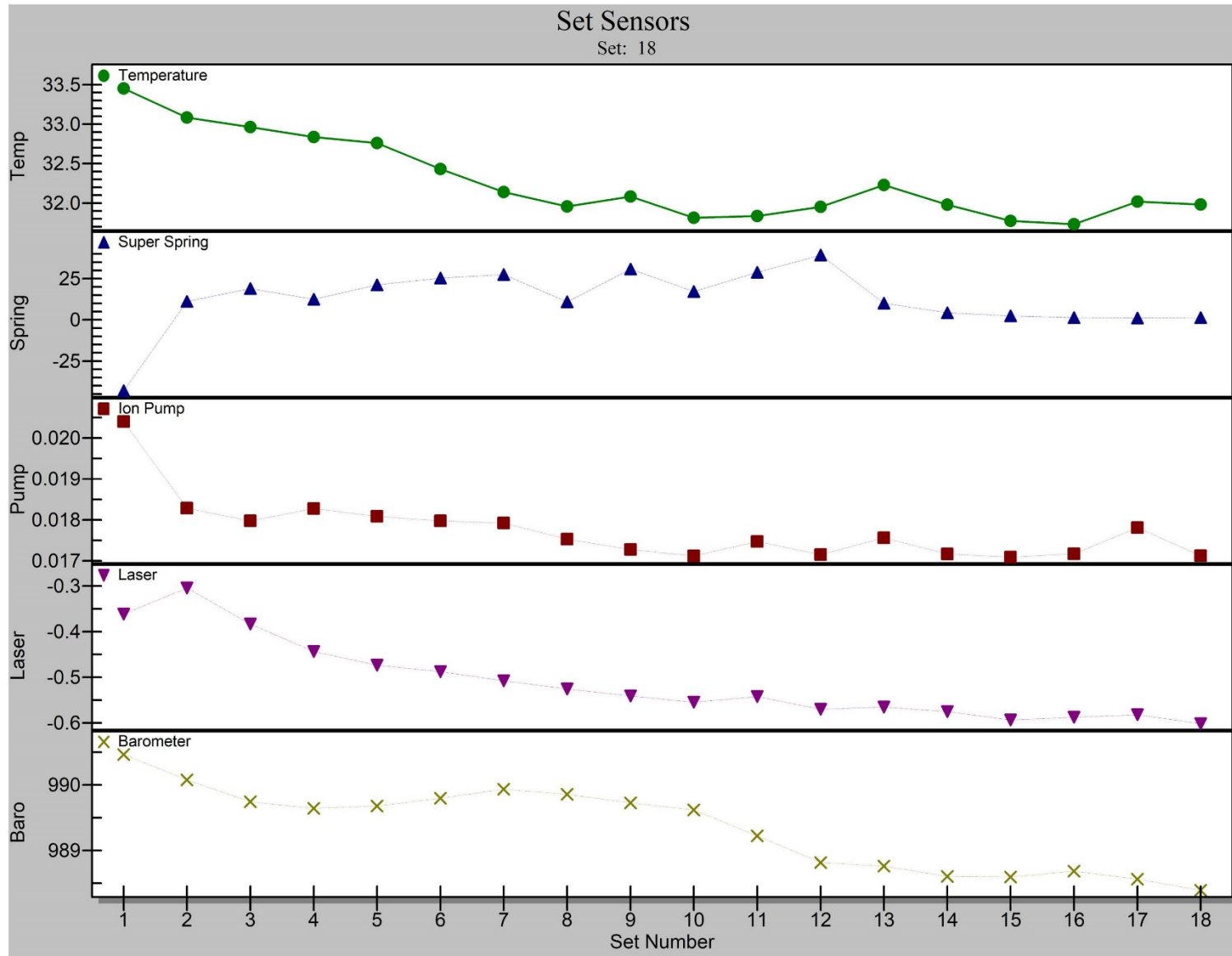
# Set File

Source Data Filename: CA20190514  
 g Acquisition Version: 9.160516  
 g Processing Version: 9.120423

Set	Time	DOY	Year	Gravity	Sigma	Error	Uncert	Tide	Load	Baro	Polar	Transfer	Refxo	Tilt	Diffraction	SelfAttract	Temp	Pres	Chan5	Chan6	Chan7	Chan8	Chan9	Chan10	Accept	Reject
1	14:33:23	134	2019	980963800.906	440.720	31.321	31.321	-54.776	-0.686	3.646	-0.821	419.759	0.004	0.000	0.000	0.000	33.452	990.463	-0.008	366.227	270.566	0.000	0.000	0.000	198	2
2	15:33:22	134	2019	980963812.020	70.324	5.010	5.010	-53.534	0.187	3.530	-0.821	419.759	0.004	0.000	0.000	0.000	33.084	990.077	-0.006	280.203	173.731	0.000	0.000	0.000	197	3
3	16:33:19	134	2019	980963813.446	14.253	1.013	1.013	-43.039	1.048	3.430	-0.821	419.759	0.004	0.000	0.000	0.000	32.963	989.743	-0.005	260.601	131.369	0.000	0.000	0.000	198	2
4	17:33:20	134	2019	980963811.127	14.888	1.055	1.055	-26.207	1.673	3.400	-0.821	419.759	0.004	0.000	0.000	0.000	32.837	989.643	-0.005	229.085	100.312	0.000	0.000	0.000	199	1
5	18:33:18	134	2019	980963810.905	7.535	0.533	0.533	-7.990	1.887	3.410	-0.821	419.759	0.004	0.000	0.000	0.000	32.760	989.677	-0.005	209.840	75.235	0.000	0.000	0.000	200	0
6	19:33:18	134	2019	980963813.118	6.411	0.453	0.453	6.076	1.621	3.446	-0.821	419.759	0.004	0.000	0.000	0.000	32.431	989.797	-0.006	197.095	60.185	0.000	0.000	0.000	200	0
7	20:33:18	134	2019	980963812.696	6.613	0.468	0.468	11.321	0.920	3.488	-0.821	419.759	0.004	0.000	0.000	0.000	32.140	989.935	-0.005	178.550	44.670	0.000	0.000	0.000	200	0
8	21:33:20	134	2019	980963813.253	6.815	0.483	0.483	5.326	-0.058	3.464	-0.821	419.759	0.004	0.000	0.000	0.000	31.957	989.858	-0.005	164.849	29.060	0.000	0.000	0.000	199	1
9	22:33:18	134	2019	980963813.247	5.617	0.398	0.398	-11.320	-1.081	3.425	-0.821	419.759	0.004	0.000	0.000	0.000	32.084	989.726	-0.005	159.688	25.312	0.000	0.000	0.000	199	1
10	23:33:19	134	2019	980963813.211	5.468	0.391	0.391	-35.168	-1.901	3.393	-0.821	419.759	0.004	0.000	0.000	0.000	31.813	989.619	-0.005	158.235	20.684	0.000	0.000	0.000	196	4
11	00:33:17	135	2019	980963812.332	6.505	0.461	0.461	-60.622	-2.314	3.274	-0.821	419.759	0.004	0.000	0.000	0.000	31.836	989.224	-0.005	148.452	15.834	0.000	0.000	0.000	199	1
12	01:33:16	135	2019	980963812.518	6.497	0.461	0.461	-81.523	-2.211	3.152	-0.821	419.759	0.004	0.000	0.000	0.000	31.953	988.816	-0.005	138.980	9.608	0.000	0.000	0.000	199	1
13	02:33:18	135	2019	980963812.144	6.400	0.453	0.453	-92.555	-1.604	3.136	-0.821	419.759	0.004	0.000	0.000	0.000	32.229	988.763	-0.007	142.985	12.275	0.000	0.000	0.000	200	0
14	03:33:18	135	2019	980963811.351	6.231	0.441	0.441	-90.599	-0.631	3.089	-0.821	419.759	0.004	0.000	0.000	0.000	31.978	988.605	-0.007	143.455	-0.390	0.000	0.000	0.000	200	0
15	04:33:19	135	2019	980963812.495	6.511	0.462	0.462	-75.545	0.482	3.086	-0.821	419.759	0.004	0.000	0.000	0.000	31.775	988.596	-0.007	136.678	-2.749	0.000	0.000	0.000	199	1
16	05:33:19	135	2019	980963811.701	6.407	0.454	0.454	-50.315	1.471	3.112	-0.821	419.759	0.004	0.000	0.000	0.000	31.732	988.684	-0.007	121.714	-3.055	0.000	0.000	0.000	199	1
17	06:33:35	135	2019	980963812.124	9.377	0.675	0.675	-20.037	2.104	3.076	-0.821	419.759	0.004	0.000	0.000	0.000	32.019	988.564	-0.007	116.202	-0.130	0.000	0.000	0.000	193	7
18	07:33:18	135	2019	980963811.659	6.347	0.449	0.449	8.448	2.228	3.025	-0.821	419.759	0.004	0.000	0.000	0.000	31.982	988.394	-0.007	118.785	-6.920	0.000	0.000	0.000	200	0



**Figure 2.** Plot of the set gravity values (1 set = 200 drops).



**Figure 3.** Plot of the set sensor parameters (1 set = 200 drops).

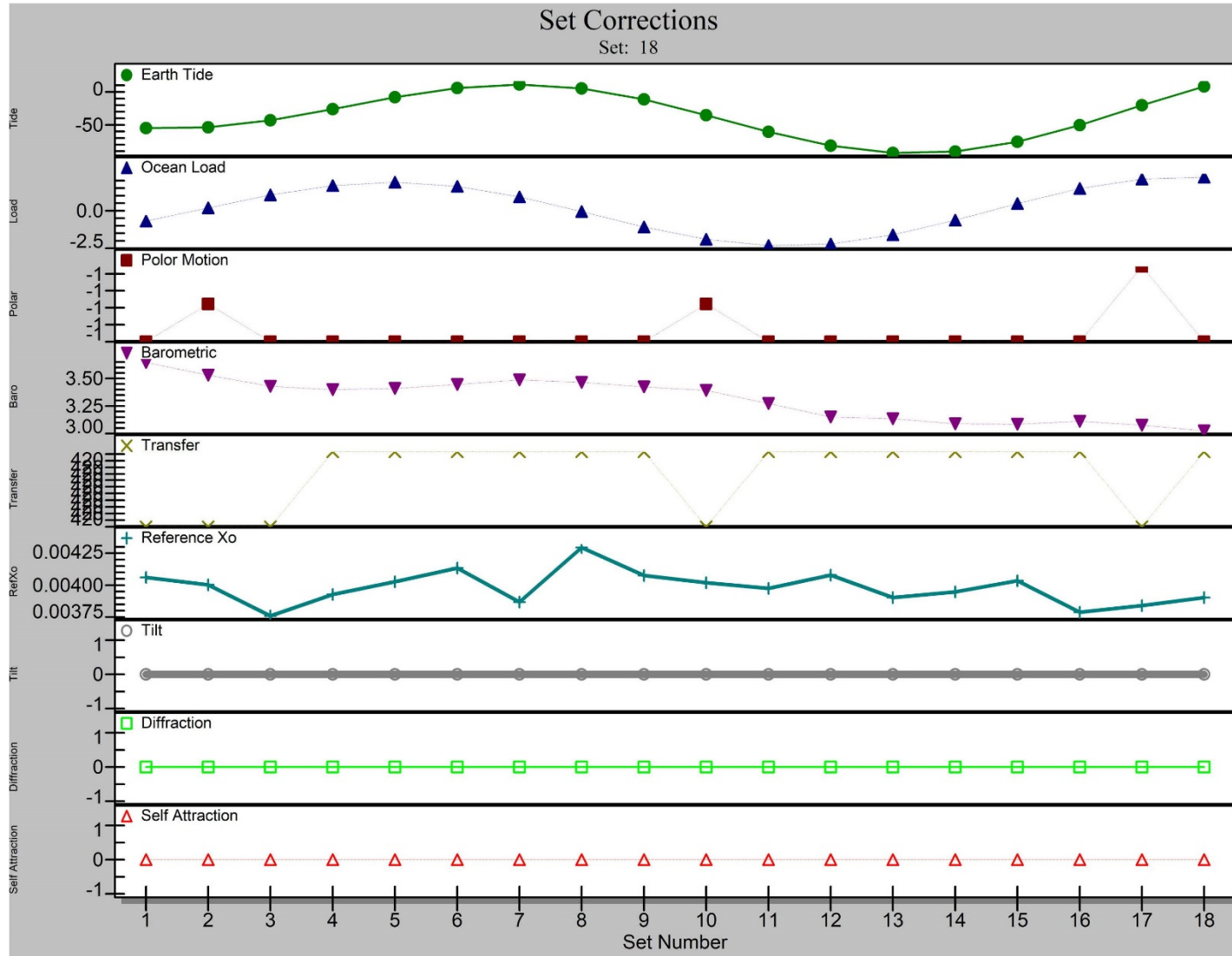


Figure 4. Plot of the set corrections values (1 set = 200 drops).