



**ABSOLUTE GRAVITY MEASUREMENTS AT THE ALPINE
RESEARCH CENTRE IN OBERGURGL (AUSTRIA)
IN JUNE 2019**

Final Report

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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

Foreword

This report contains the results of absolute gravity measurements carried out at Alpine Research Centre (University of Innsbruck) in Obergurgl. The measurements took place on the pier 0-173-02 (Figure 1) in June 2019.

The absolute gravimeter FG5X#216 was operated by Olivier Francis and Sajad Tabibi from the University of Luxembourg.

The measurements are part of an on-going research collaboration between the Geophysics Laboratory of the University of Luxembourg and Christian Ullrich from the Bundesamt für Eich- und Vermessungswesen (BEV, Federal Office of Metrology and Surveying) in Vienna, Austria.

It is the third time we measured at this site. Measurements were previously performed in June and September 2018.



Figure 1. Pier at the Alpine Research Centre (University of Innsbruck) in Obergurgl.

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 has 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 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. 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 desired height (1.22 in the present report). Its determination requires relative measurements using a smaller and portable relative gravimeter. We used $-1.82 \mu\text{Gal}/\text{cm}$. This value was provided by Christian Ullrich.

Results of the absolute gravity measurements

The FG5X#216 operated from the 3rd of June 2019 at 21:40 UTC until the 5th of June 2019 at 05:40 UTC. A total of 34 sets of 100 drops (1 drop /10 sec) were taken with a rate of 1 set per hour. It represents a total of 3400 drops.

Site	Gravity value/ μGal	Mean Set Standard Deviation/ μGal
AGM @ 1.22 m	980 239 661.46	0.71

Comparisons with the previous measurements

The results of all the measurements we carried out so far at the Obergurllg site are listed in the table below. We observe the expected annual gravity changes due to the snow cover variation between the summer and the winter. A longer gravity time series can be found in Arneitz et al. (2013). The authors made a thorough analysis of the observations and provide a model explaining the trend and variation in gravity due to the glacial ablation in the vicinity of the station. From this study, we found as expected the gravity values should be lower at the beginning of the summer due to the snow accumulation during the winter. We should also observe an increase in the gravity values from year to year. However, this positive trend is not visible between June 2018 and June 2019. At this stage, the exceptionally long winter of 2019 (there was still snow end of June this year) is a reasonable explanation for the slight gravity decrease between June 2018 and 2019 instead of a few microgal increase as observed during the last decades.

Date	Gravity value/ μGal	Mean Set Standard Deviation/ μGal
5 June 2018	980 239 662.94	0.71
18 September 2018	980 239 670.04	0.66
4 June 2019	980 239 661.46	0.71

Reference

- Arneitz, P., Meurers, B., Ruess, D., Ullrich, C., Abermann, J., and Kuhn, M.: Gravity effect of glacial ablation in the Eastern Alps - observation and modeling, *The Cryosphere*, 7, 491-498, <https://doi.org/10.5194/tc-7-491-2013>, 2013.
- 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: Alpine Research Centre (University of Innsbruck) in Obergurgl			
City:	Obergurgl	Country:	Austria
Location:	Alpine Research Centre	Particularity:	
Situation:	Pier 0-173-02	Remarks:	
Date:	3-5 June 2019		
Code number:	0-173-02		
Latitude:	46.86709 degrees		
Longitude:	11.02489 degrees		
Elevation:	1935.40 m		
Gradient:	-1.82 μ gal/cm		
Reference height	0.1305 m + 1.2583 m = 1.3888 m		
Meter:	FG5X		
S/N:	216		
Tidal corrections using observed tidal parameters			
Polar motion correction		Air pressure correction	
X-coordinate	0.1211	Arc seconds	Nominal air pressure: 801.35 mbar
Y-coordinate	0.4314	Arc seconds	Barometric admittance factor 0.3 μ gal/mbar
Gravity			
Set gravity mean:	980 239 661.46	microgal	
Set std. dev.:	0.71	microgal	
Mean std. dev.:	3.96	microgal	
Number of sets:	34		
Number of drops per set:	100		
Drop interval:	10 seconds		
Set interval:	60 minutes		
Nominal/datum height:	1.22 m		
Author: O. Francis		University of Luxembourg	
Date: September 26, 2019			

Project file

Micro-g LaCoste g Processing Report
File Created: 09/13/19, 15:33:04

Project Name: OB201906
g Acquisition Version: 9.160516
g Processing Version: 9.120423

Company/Institution:
Operator: Olivier Francis

Station Data

Name: OBERGURGL
Site Code: 0-173-02
Lat: 46.86709 Long: 11.02489 Elev: 1935.40 m
Setup Height: 13.05 cm
Transfer Height: 122.00 cm
Actual Height: 138.88 cm
Gradient: -1.820 μ Gal/cm
Nominal Air Pressure: 801.35 mBar
Barometric Admittance Factor: 0.30
Polar Motion Coord: 0.1211 " 0.4314 "
Earth Tide (ETGTAB) Selected
Potential Filename: C:\gData\gWavefiles\ETCPOT.dat
Delta Factor Filename: D:\ABSOLU\DATA\INT\OceanLoad-OBERGURGL.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: D:\ABSOLU\DATA\INT\OceanLoad-OBERGURLP.olf

Waves: M2 S2 K1 O1 N2 P1 K2 Q1 Mf Mm Ssa
Amplitude (μ Gal): 1.447 0.478 0.134 0.135 0.294 0.047 0.125 0.037 0.000 0.000 0.000
Phase (deg): 56.2 28.4 71.9 -188.8 73.5 84.3 26.6 -131.8 0.0 0.0 0.0

Instrument Data

Meter Type: FG5
Meter S/N: X216
Factory Height: 125.83 cm
Rubidium Frequency: 10000000.00000 Hz
Laser: WEO100 (242)
ID: 632.99117754 nm (-0.05 V)
IE: 632.99119473 nm (-0.53 V)
IF: 632.99121259 nm (-0.95 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: 8333.340 Hz

Processing Results

Date: 06/04/19
Time: 13:39:37
DOY: 155
Year: 2019
Time Offset (D h:m:s): 0 0:0:0
Gravity: 980239661.46 μGal
Set Scatter: 0.71 μGal
Measurement Precision: 0.12 μGal
Total Uncertainty: 0.12 μGal
Number of Sets Collected: 34
Number of Sets Processed: 33
Set #s Processed:
2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34
Number of Sets NOT Processed: 1
Set #s NOT Processed: 1
Number of Drops/Set: 100
Total Drops Accepted: 3279
Total Drops Rejected: 21
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: 10 sec
Number of Sets: 34
Number of Drops: 100

Gravity Corrections

Earth Tide (ETGTAB): -28.06 μGal
Ocean Load: -0.05 μGal
Polar Motion: -0.69 μGal
Barometric Pressure: 1.70 μGal
Transfer Height: 30.72 μGal
Reference Xo: 0.00 μGal

Uncertainties

Sigma Reject: 3.00
Earth Tide Factor: 0.000
Average Earth Tide Uncertainty: 0.00 μGal
Ocean Load Factor: 0.00
Average Ocean Load Uncertainty: 0.00 μGal
Barometric: 0.00 μGal
Polar Motion: 0.00 μGal
Laser: 0.00 μGal
Clock: 0.00 μGal
System Type: 0.00 μGal
Tidal Swell: 0.00 μGal
Water Table: 0.00 μGal
Unmodeled: 0.00 μGal
System Setup: 0.00 μGal
Gradient: 0.000 μGal (0.000 $\mu\text{Gal}/\text{cm}$)
Files Merged:

OB20190603.fg5
OB20190604.fg5

Set File

Source Data Filename: OB201906

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			
2	21:50:44	154	2019	980239660.516				3.578	0.358	0.358	-62.872	1.814	2.619	-0.694	30.722	0.002	0.000	0.000	0.000	30.663810.081	-0.011	158.320		51.780	0.000	0.000	0.000	100	0
3	22:50:43	154	2019	980239661.755				3.698	0.374	0.374	-52.771	1.510	2.543	-0.694	30.722	0.002	0.000	0.000	0.000	30.637809.826	-0.008	128.265		30.847	0.000	0.000	0.000	98	2
4	23:50:49	154	2019	980239660.534				4.020	0.402	0.402	-50.513	0.826	2.475	-0.694	30.722	0.002	0.000	0.000	0.000	30.476809.599	-0.007	116.950		18.140	0.000	0.000	0.000	100	0
5	00:50:51	155	2019	980239660.654				3.531	0.355	0.355	-56.916	-0.058	2.309	-0.694	30.722	0.003	0.000	0.000	0.000	30.432809.048	-0.007	101.909		8.788	0.000	0.000	0.000	99	1
6	01:50:49	155	2019	980239659.873				3.358	0.336	0.336	-69.472	-0.910	2.215	-0.694	30.722	0.002	0.000	0.000	0.000	30.358808.735	-0.007	89.750	4.890	0.000	0.000	0.000	100	0	
7	02:50:49	155	2019	980239660.618				3.793	0.379	0.379	-83.111	-1.512	2.079	-0.694	30.722	0.002	0.000	0.000	0.000	30.310808.278	-0.006	86.050	-1.600	0.000	0.000	0.000	100	0	
8	03:50:53	155	2019	980239661.145				3.576	0.359	0.359	-91.496	-1.706	2.023	-0.694	30.722	0.002	0.000	0.000	0.000	30.240808.092	-0.006	77.091	-6.273	0.000	0.000	0.000	99	1	
9	04:50:34	155	2019	980239660.322				4.478	0.459	0.459	-88.818	-1.441	1.998	-0.694	30.722	0.002	0.000	0.000	0.000	30.339808.011	-0.006	78.274	-10.379	0.000	0.000	0.000	95	5	
10	05:50:49	155	2019	980239661.027				8.617	0.862	0.862	-71.317	-0.777	1.998	-0.694	30.722	0.002	0.000	0.000	0.000	30.266808.011	-0.006	62.650	-12.380	0.000	0.000	0.000	100	0	
11	06:35:21	155	2019	980239661.901				3.867	0.387	0.387	-48.528	-0.128	1.964	-0.694	30.722	0.002	0.000	0.000	0.000	30.675807.897	-0.006	57.300	-10.280	0.000	0.000	0.000	100	0	
12	07:35:26	155	2019	980239662.541				3.727	0.373	0.373	-6.967	0.782	1.922	-0.694	30.722	0.002	0.000	0.000	0.000	30.723807.757	-0.006	65.870	-15.260	0.000	0.000	0.000	100	0	
13	08:35:23	155	2019	980239662.936				3.500	0.352	0.352	41.135	1.513	1.872	-0.694	30.722	0.002	0.000	0.000	0.000	30.859807.590	-0.006	62.919	-13.040	0.000	0.000	0.000	99	1	
14	09:35:26	155	2019	980239662.355				3.755	0.375	0.375	87.631	1.876	1.877	-0.694	30.722	0.002	0.000	0.000	0.000	31.027807.605	-0.006	66.160	-21.710	0.000	0.000	0.000	100	0	
15	10:35:30	155	2019	980239661.877				8.572	0.862	0.862	123.687		1.769	1.837	-0.694	30.722	0.002	0.000	0.000	0.000	31.055807.475	-0.006	55.303	-12.838	0.000	0.000	0.000	99	1
16	11:35:26	155	2019	980239662.115				3.436	0.344	0.344	142.174		1.209	1.701	-0.694	30.722	0.002	0.000	0.000	0.000	31.205807.021	-0.006	61.090	-16.470	0.000	0.000	0.000	100	0
17	12:35:23	155	2019	980239661.936				3.317	0.333	0.333	139.489		0.330	1.574	-0.694	30.722	0.002	0.000	0.000	0.000	31.169806.597	-0.006	72.475	-17.879	0.000	0.000	0.000	99	1
18	13:35:26	155	2019	980239662.038				3.862	0.386	0.386	116.137		-0.657	1.498	-0.694	30.722	0.002	0.000	0.000	0.000	31.158806.344	-0.006	62.320	-16.800	0.000	0.000	0.000	100	0
19	14:35:26	155	2019	980239661.014				3.622	0.362	0.362	76.844	-1.506	1.473	-0.694	30.722	0.002	0.000	0.000	0.000	31.134806.260	-0.006	57.080	-24.680	0.000	0.000	0.000	100	0	
20	15:35:26	155	2019	980239661.243				3.739	0.374	0.374	29.263	-2.007	1.391	-0.694	30.722	0.002	0.000	0.000	0.000	31.160805.988	-0.006	64.570	-24.570	0.000	0.000	0.000	100	0	
21	16:35:31	155	2019	980239661.018				3.344	0.336	0.336	-17.893	-2.035	1.357	-0.694	30.722	0.002	0.000	0.000	0.000	31.075805.872	-0.006	64.283	-19.566	0.000	0.000	0.000	99	1	
22	17:35:26	155	2019	980239660.764				3.662	0.366	0.366	-56.644	-1.584	1.449	-0.694	30.722	0.002	0.000	0.000	0.000	31.079806.179	-0.006	66.620	-25.200	0.000	0.000	0.000	100	0	
23	18:35:26	155	2019	980239661.111				4.042	0.404	0.404	-82.025	-0.764	1.515	-0.694	30.722	0.002	0.000	0.000	0.000	31.043806.399	-0.006	63.950	-25.860	0.000	0.000	0.000	100	0	
24	19:35:26	155	2019	980239662.319				3.509	0.351	0.351	-92.477	0.222	1.484	-0.694	30.722	0.002	0.000	0.000	0.000	30.768806.296	-0.006	57.000	-22.150	0.000	0.000	0.000	100	0	
25	20:35:25	155	2019	980239661.860				3.590	0.361	0.361	-90.120	1.131	1.539	-0.694	30.722	0.002	0.000	0.000	0.000	30.769806.479	-0.006	57.091	-24.131	0.000	0.000	0.000	99	1	
26	21:35:26	155	2019	980239661.675				3.963	0.398	0.398	-79.785	1.742	1.503	-0.694	30.722	0.002	0.000	0.000	0.000	30.719806.361	-0.006	53.010	-24.283	0.000	0.000	0.000	99	1	
27	22:35:23	155	2019	980239661.443				3.539	0.356	0.356	-67.515	1.908	1.484	-0.694	30.722	0.003	0.000	0.000	0.000	30.525806.295	-0.006	54.010	-25.576	0.000	0.000	0.000	99	1	
28	23:35:26	155	2019	980239662.232				3.823	0.382	0.382	-58.769	1.596	1.430	-0.694	30.722	0.002	0.000	0.000	0.000	30.652806.116	-0.006	54.720	-24.460	0.000	0.000	0.000	100	0	
29	00:35:26	156	2019	980239661.537				3.961	0.396	0.396	-57.040	0.893	1.339	-0.694	30.722	0.002	0.000	0.000	0.000	30.506805.812	-0.006	49.830	-24.080	0.000	0.000	0.000	100	0	
30	01:35:28	156	2019	980239660.923				3.650	0.367	0.367	-62.868	-0.014	1.217	-0.694	30.722	0.002	0.000	0.000	0.000	30.549805.407	-0.006	50.131	-30.394	0.000	0.000	0.000	99	1	
31	02:35:26	156	2019	980239661.115				3.415	0.341	0.341	-73.761	-0.889	1.092	-0.694	30.722	0.002	0.000	0.000	0.000	30.619804.989	-0.006	49.580	-28.960	0.000	0.000	0.000	100	0	
32	03:35:26	156	2019	980239661.993				3.176	0.319	0.319	-84.919	-1.505	1.087	-0.694	30.722	0.002	0.000	0.000	0.000	30.510804.974	-0.006	42.162	-31.172	0.000	0.000	0.000	99	1	
33	04:35:22	156	2019	980239661.822				3.683	0.370	0.370	-90.511	-1.705	1.135	-0.694	30.722	0.003	0.000	0.000	0.000	30.534805.132	-0.006	48.040	-32.061	0.000	0.000	0.000	99	1	
34	05:35:31	156	2019	980239661.648				3.226	0.326	0.326	-85.298	-1.434	1.091	-0.694	30.722	0.002	0.000	0.000	0.000	30.622804.986	-0.006	43.347	-33.908	0.000	0.000	0.000	98	2	

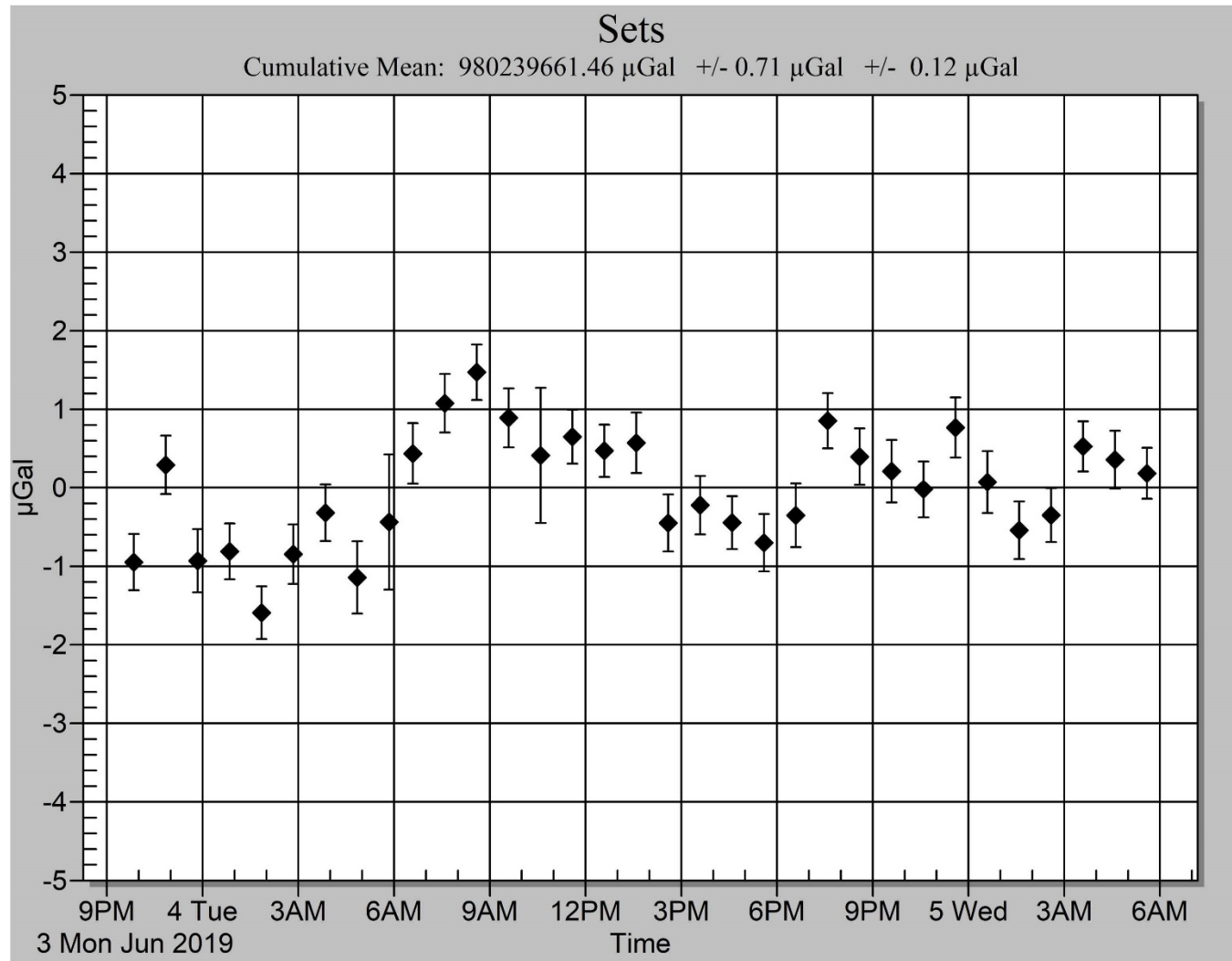


Figure 2. Plot of the set gravity values (1 set = 100 drops).

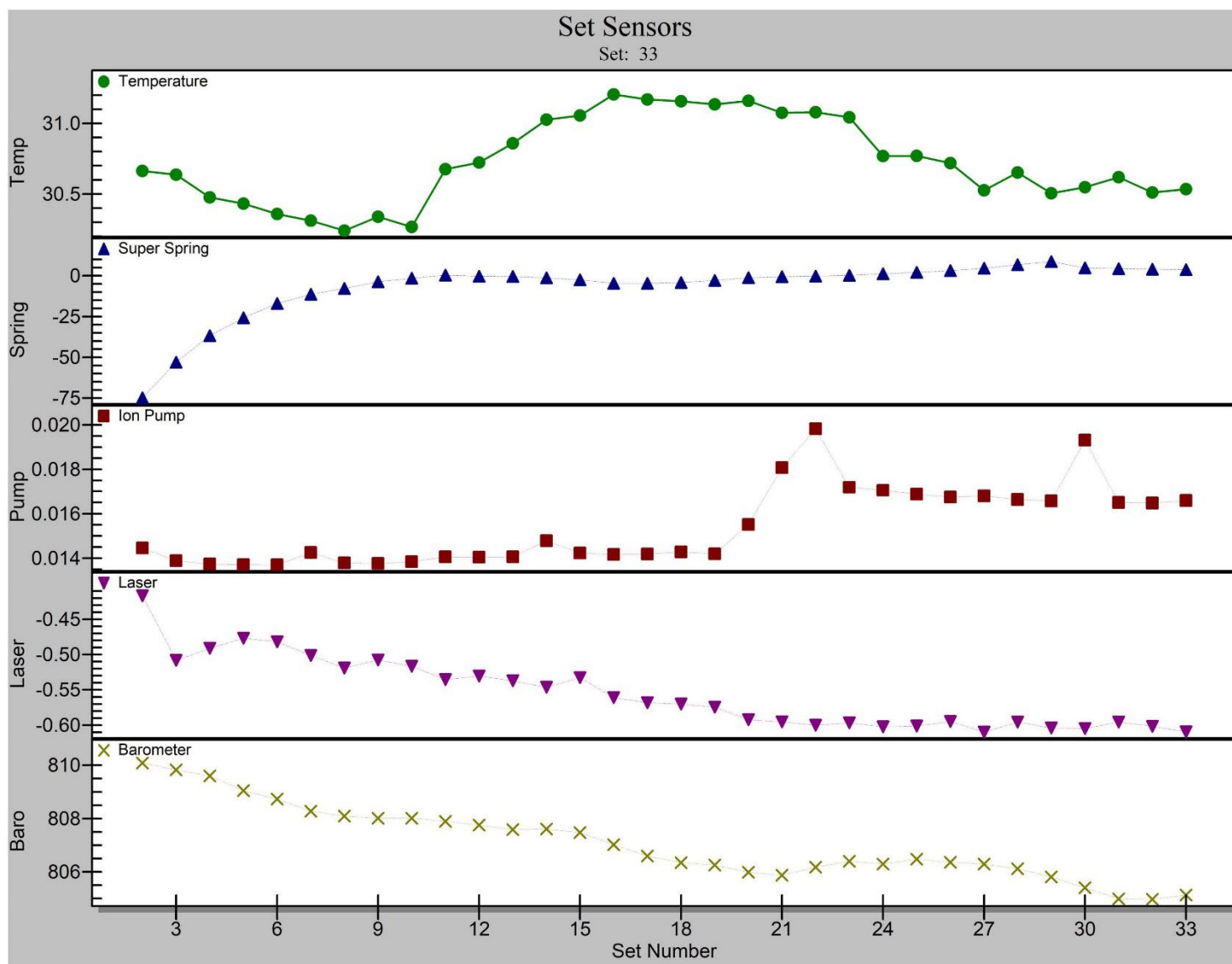


Figure 3. Plot of the set sensor parameters (1 set = 100 drops).

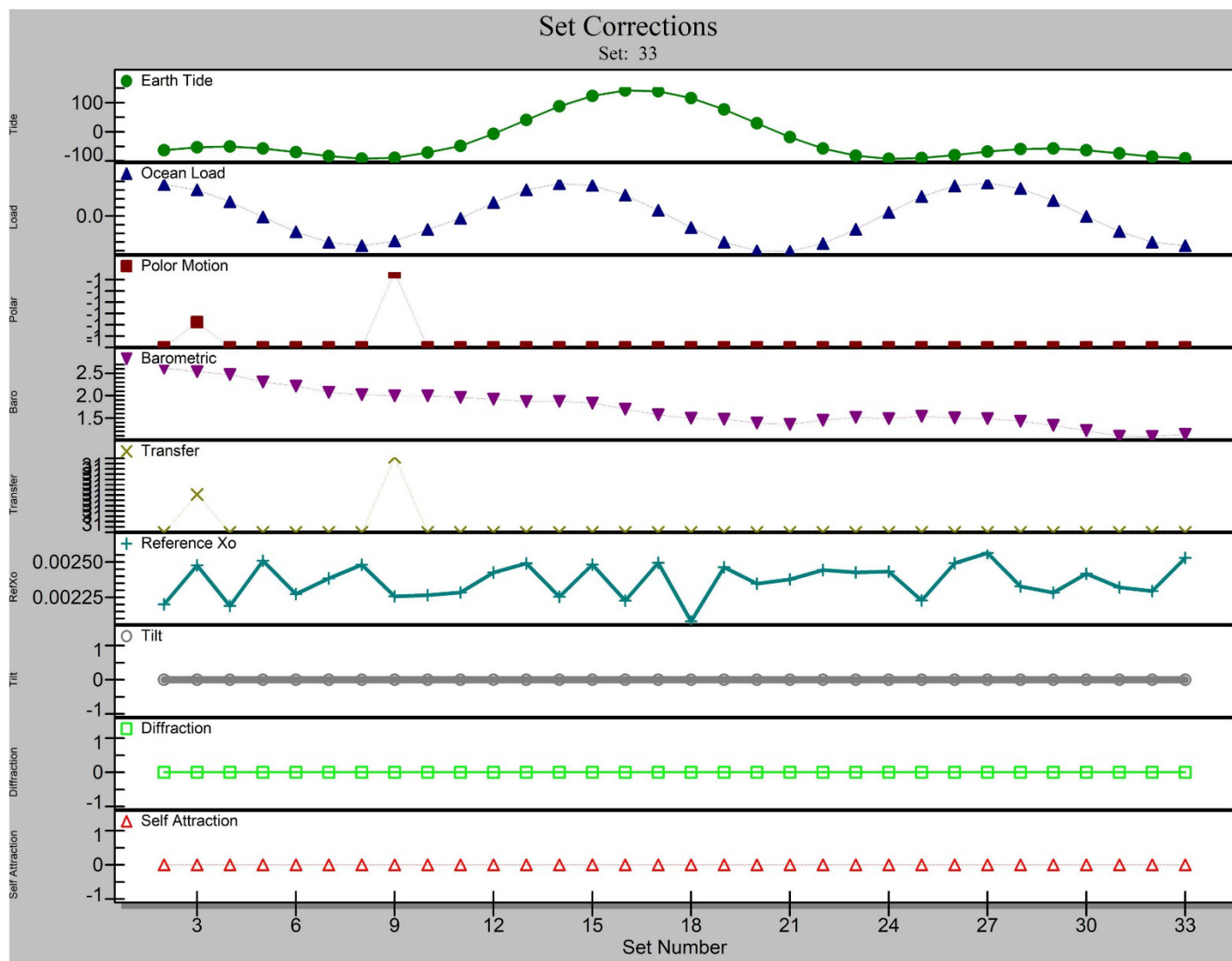


Figure 4. Plot of the set corrections values (1 set = 100 drops).