



**ABSOLUTE GRAVITY MEASUREMENTS AT THE BASE OF  
THE GROSSGLOCKNER IN THE AUSTRIAN ALPS  
IN SEPTEMBER 2021**

**Final Report**

**June 2022**

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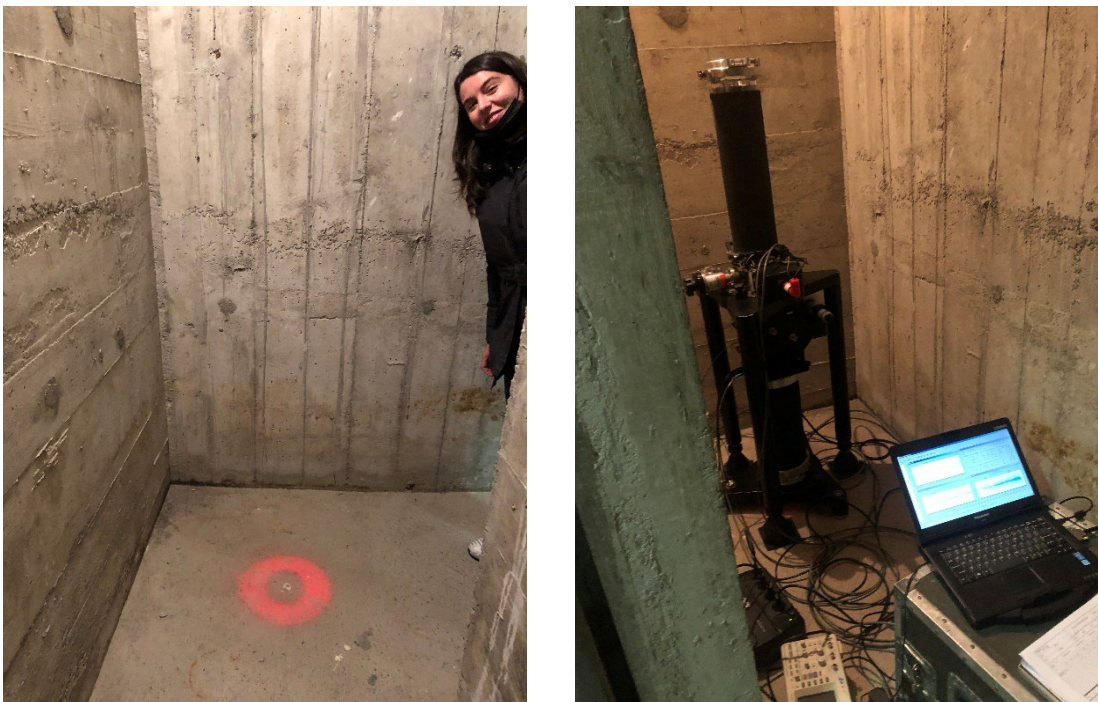
## Foreword

This report contains the results of absolute gravity measurements carried out at the base of the Grossglockner in the central eastern Alps during the month of September 2021. The Grossglockner is the highest mountain in Austria with an altitude of 3798 m. Its eastern slope is covered by the Pasterze, which is the largest glacier in the eastern Alps. It has a length of 8.4 km and undergoes a continuous and fast retreat due to the climate change and global warming. The glacier lost half of its volume since 1851.

The gravity benchmark is located in the Visitor Centre Kaiser-Franz-Josefs-Hohe (Figure 1). The absolute gravimeter FG5X#216 was operated by Olivier Francis and Raquel Navarro Buendía from the University of Luxembourg.

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

It is the first time we measured at this site. The Austrian team already performed measurements for several years. In addition, a GPS permanent station was installed while the gravity measurements were performed.



**Figure 1.** Pier at the Visitor Centre Kaiser-Franz-Josefs-Hohe at the base of the Grossglockner

## 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  $-2.0228 \mu\text{Gal}/\text{cm}$ . This value was provided by Christian Ullrich.

## Results of the absolute gravity measurements

The FG5X#216 operated from the 27<sup>th</sup> of September 2021 at 10:20 UTC until the 28<sup>th</sup> of September 2021 at 07:30 UTC. A total of 45 sets of 100 drops (1 drop every 10 sec) were taken at a rate of 2 sets per hour. It represents a total of 4500 drops. For the final result, the two first sets of data are eliminated as the electronics of the gravimeter was still warming up.

Site	Gravity value/ $\mu\text{Gal}$	Mean Set Standard Deviation/ $\mu\text{Gal}$
KFJH @ 1.22 m	980 168 619.34	0.70

## 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: Visitor Centre Kaiser-Franz-Josefs-Hoehle</b>			
City:	Grossglockner	Country:	Austria
Location:	Central Eastern Alps	Particularity:	
Situation:		Remarks:	
Date:	27-28 September 2021		
Code number:	KFJH		
Latitude:	47.0763 degrees		
Longitude:	12.7516 degrees		
Elevation:	2365.13 m		
Gradient:	-2.0228 $\mu\text{gal/cm}$		
Reference height	0. 1230 m + 1.2579 m = 1.3809 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	0.2232	Arc seconds	Nominal air pressure: 759.57 mbar
Y-coordinate	0.2851	Arc seconds	Barometric admittance factor 0.3 $\mu\text{gal/mbar}$
<b>Gravity</b>			
Set gravity mean:	<b>980 168 619.34</b>		Microgal
Set standard deviation:	<b>0.70</b>		microgal
Mean standard deviation:	6.14		microgal
Number of sets:	43		
Number of drops per set:	100		
Drop interval:	10 seconds		
Set interval:	30 minutes		
Nominal/datum height:	1.22 m		
Author: O. Francis			University of Luxembourg
Date: 8 June 2022			

# Project file

Micro-g LaCoste g Processing Report  
File Created: 07/08/22, 06:49:12

Project Name: KF2010927  
g Acquisition Version: 9.160516  
g Processing Version: 9.120423

Company/Institution: University of Luxembourg  
Operator: Olivier FRANCIS

## Station Data

Name: KFJH  
Site Code:  
Lat: 47.07630 Long: 12.75160 Elev: 2365.13 m  
Setup Height: 12.30 cm  
Transfer Height: 122.00 cm  
Actual Height: 138.09 cm  
Gradient: -2.023  $\mu$ Gal/cm  
Nominal Air Pressure: 759.57 mBar  
Barometric Admittance Factor: 0.30  
Polar Motion Coord: 0.2232 " 0.2851 "  
Earth Tide (ETGTAB) Selected  
Potential Filename: C:\gData\gWavefiles\ETCPOT.dat  
Delta Factor Filename: C:\gData\OceanLoad-KFJH.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-KFJH.olf

Waves:	M2	S2	K1	O1	N2	P1	K2	Q1	Mf	Mm	Ssa
Amplitude ( $\mu$ Gal):	1.311	0.433	0.119	0.132	0.266	0.042	0.113	0.035	0.000	0.000	0.000
Phase (deg):	52.5	24.9	72.8	-192.2	69.7	85.4	22.7	-136.9	0.0	0.0	0.0

## Instrument Data

Meter Type: FG5  
Meter S/N: X216  
Factory Height: 125.79 cm  
Rubidium Frequency: 10000000.01121 Hz  
Laser: WEO100 (242)  
ID: 632.99117754 nm ( 0.01 V)  
IE: 632.99119473 nm (-0.49 V)  
IF: 632.99121259 nm (-0.91 V)  
IG: 632.99123023 nm (-1.29 V)  
IH: 632.99136890 nm (-1.66 V)  
II: 632.99139822 nm ( 4.00 V)  
IJ: 632.99142704 nm ( 5.00 V)  
Modulation Frequency: 8333.350 Hz

## Processing Results

Date: 09/27/21  
Time: 20:55:33  
DOY: 270  
Year: 2021  
Time Offset (D h:m:s): 0 0:0:0  
Gravity: 980168619.34  $\mu$ Gal  
Set Scatter: 0.70  $\mu$ Gal  
Measurement Precision: 0.11  $\mu$ Gal  
Total Uncertainty: 1.59  $\mu$ Gal  
Number of Sets Collected: 45  
Number of Sets Processed: 43  
Set #s Processed:  
3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,  
42,43,44,45  
Number of Sets NOT Processed: 2  
Set #s NOT Processed: 1,2  
Number of Drops/Set: 100  
Total Drops Accepted: 4275  
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: 30 min  
Drop Interval: 10 sec  
Number of Sets: 48  
Number of Drops: 100

Gravity Corrections  
Earth Tide (ETGTAB): -12.62  $\mu$ Gal  
Ocean Load: 0.10  $\mu$ Gal  
Polar Motion: -2.96  $\mu$ Gal  
Barometric Pressure: 2.95  $\mu$ Gal  
Transfer Height: 32.55  $\mu$ Gal  
Reference Xo: -0.02  $\mu$ Gal

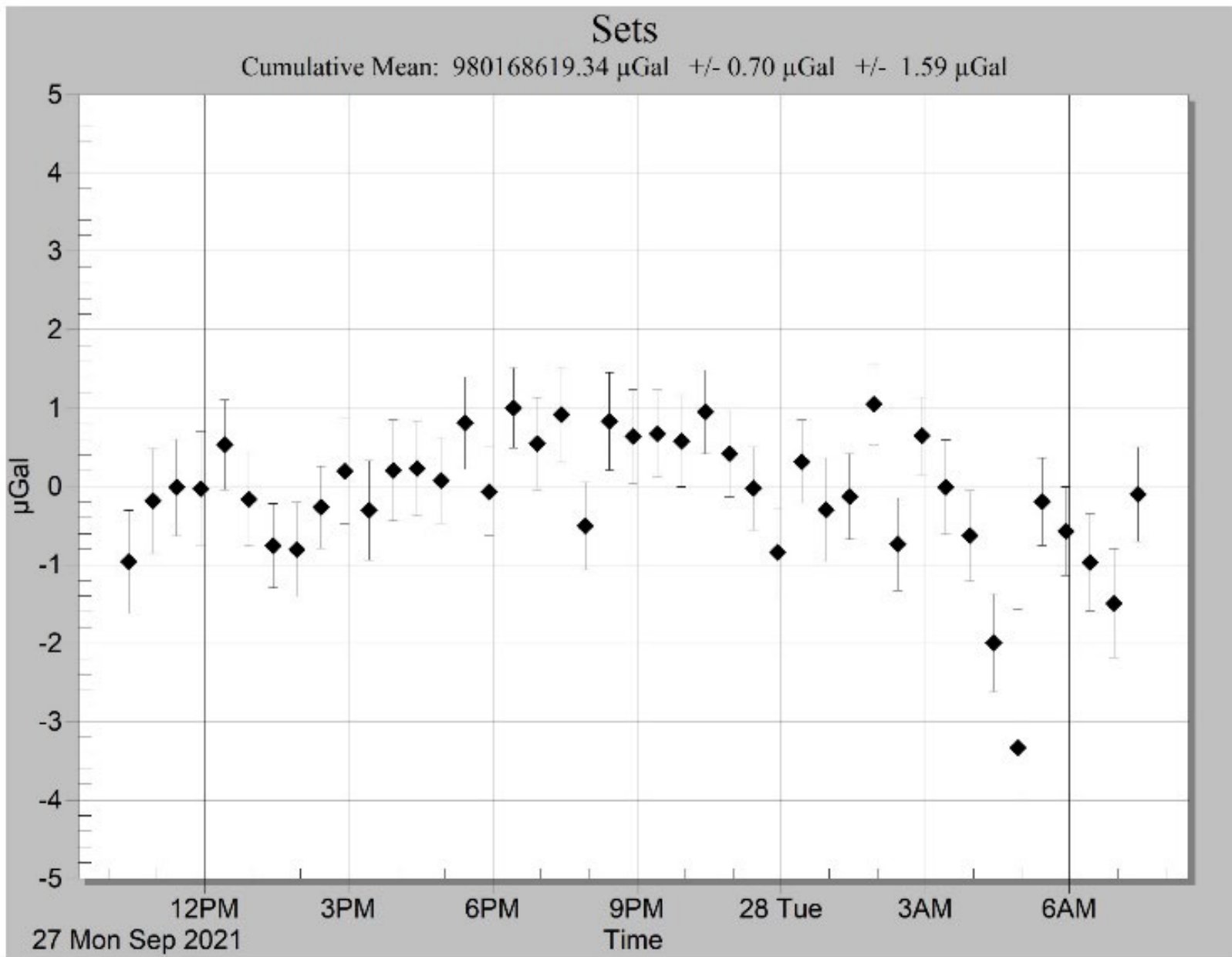
Uncertainties  
Sigma Reject: 3.00  
Earth Tide Factor: 0.000  
Average Earth Tide Uncertainty: 0.00  $\mu$ Gal  
Ocean Load Factor: 0.00  
Average Ocean Load Uncertainty: 0.00  $\mu$ Gal  
Barometric: 0.00  $\mu$ Gal  
Polar Motion: 0.00  $\mu$ Gal  
Laser: 0.00  $\mu$ Gal  
Clock: 0.10  $\mu$ Gal  
System Type: 1.50  $\mu$ Gal  
Tidal Swell: 0.00  $\mu$ Gal  
Water Table: 0.00  $\mu$ Gal  
Unmodeled: 0.00  $\mu$ Gal  
System Setup: 0.50  $\mu$ Gal  
Gradient: 0.000  $\mu$ Gal (0.000  $\mu$ Gal/cm)

# Set File

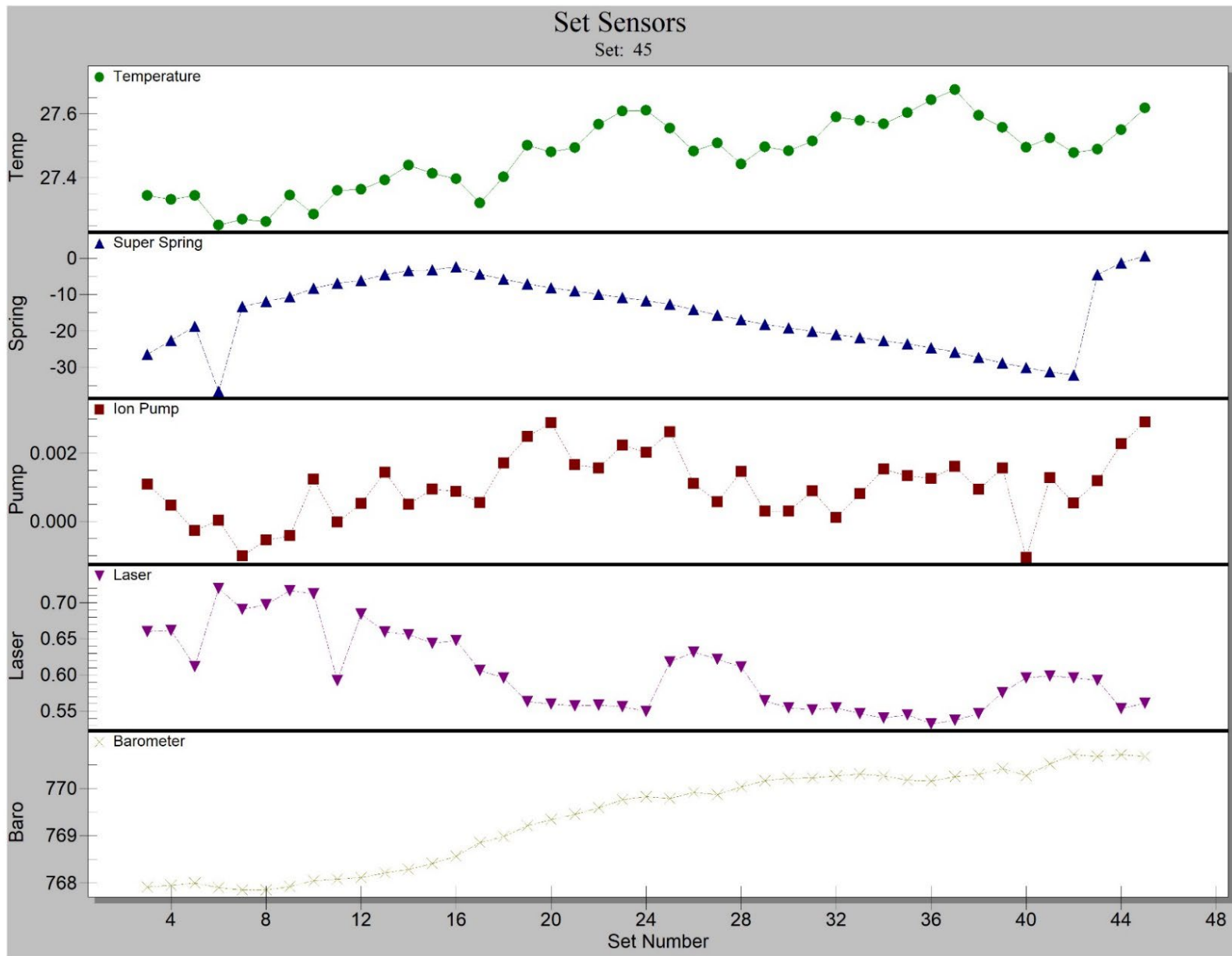
Source Data Filename: KF2010927  
 g Acquisition Version: 9.160516  
 g Processing Version: 9.120423

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
3	10:25:30	270	2021	980168618.379	6.538	0.660	1.716	-38.909	0.075	2.504	-2.955	32.547	-0.018	0.000	0.000	0.000	27.344767.916	-0.015	22.092	78.776	0.000	0.000	0.000	98	2	
4	10:55:32	270	2021	980168619.156	6.591	0.666	1.719	-41.363	0.305	2.514	-2.955	32.547	-0.018	0.000	0.000	0.000	27.331767.949	-0.015	15.816	70.337	0.000	0.000	0.000	98	2	
5	11:25:32	270	2021	980168619.332	6.119	0.618	1.701	-43.204	0.509	2.528	-2.955	32.547	-0.018	0.000	0.000	0.000	27.344767.998	-0.015	14.551	69.306	0.000	0.000	0.000	98	2	
6	11:55:30	270	2021	980168619.313	7.210	0.725	1.742	-44.658	0.677	2.500	-2.955	32.547	-0.017	0.000	0.000	0.000	27.251767.903	-0.015	14.061	55.848	0.000	0.000	0.000	99	1	
7	12:25:32	270	2021	980168619.875	5.737	0.574	1.685	-45.940	0.797	2.484	-2.955	32.547	-0.018	0.000	0.000	0.000	27.269767.849	-0.014	4.860	57.220	0.000	0.000	0.000	100	0	
8	12:55:32	270	2021	980168619.181	6.006	0.601	1.694	-47.237	0.864	2.485	-2.955	32.547	-0.017	0.000	0.000	0.000	27.262767.852	-0.014	7.150	51.270	0.000	0.000	0.000	100	0	
9	13:25:35	270	2021	980168618.587	5.371	0.540	1.674	-48.699	0.874	2.507	-2.955	32.547	-0.017	0.000	0.000	0.000	27.345767.927	-0.014	-0.535	60.899	0.000	0.000	0.000	99	1	
10	13:55:32	270	2021	980168618.538	6.033	0.603	1.695	-50.416	0.828	2.542	-2.955	32.547	-0.018	0.000	0.000	0.000	27.285768.045	-0.014	6.680	47.240	0.000	0.000	0.000	100	0	
11	14:25:32	270	2021	980168619.078	5.259	0.526	1.669	-52.435	0.730	2.552	-2.955	32.547	-0.018	0.000	0.000	0.000	27.360768.077	-0.014	-0.050	50.050	0.000	0.000	0.000	100	0	
12	14:55:32	270	2021	980168619.537	6.657	0.666	1.718	-54.729	0.587	2.563	-2.955	32.547	-0.018	0.000	0.000	0.000	27.363768.113	-0.013	-0.240	54.500	0.000	0.000	0.000	100	0	
13	15:25:32	270	2021	980168619.038	6.354	0.635	1.707	-57.217	0.410	2.594	-2.955	32.547	-0.018	0.000	0.000	0.000	27.393768.216	-0.013	-2.430	58.910	0.000	0.000	0.000	100	0	
14	15:55:32	270	2021	980168619.546	6.427	0.643	1.710	-59.766	0.211	2.615	-2.955	32.547	-0.018	0.000	0.000	0.000	27.439768.288	-0.013	-4.190	57.520	0.000	0.000	0.000	100	0	
15	16:25:32	270	2021	980168619.572	6.037	0.604	1.695	-62.198	0.004	2.653	-2.955	32.547	-0.018	0.000	0.000	0.000	27.413768.412	-0.013	-3.960	58.930	0.000	0.000	0.000	100	0	
16	16:55:36	270	2021	980168619.417	5.400	0.543	1.675	-64.312	-0.198	2.698	-2.955	32.547	-0.018	0.000	0.000	0.000	27.397768.564	-0.013	-2.939	52.040	0.000	0.000	0.000	99	1	
17	17:25:32	270	2021	980168620.152	5.876	0.588	1.690	-65.872	-0.381	2.786	-2.955	32.547	-0.018	0.000	0.000	0.000	27.321768.858	-0.013	-9.910	50.660	0.000	0.000	0.000	100	0	
18	17:55:32	270	2021	980168619.272	5.652	0.565	1.682	-66.666	-0.532	2.823	-2.955	32.547	-0.018	0.000	0.000	0.000	27.402768.982	-0.013	-2.050	42.190	0.000	0.000	0.000	100	0	
19	18:25:36	270	2021	980168620.343	5.082	0.511	1.665	-66.481	-0.643	2.892	-2.955	32.547	-0.018	0.000	0.000	0.000	27.502769.210	-0.013	-9.111	52.030	0.000	0.000	0.000	99	1	
20	18:55:32	270	2021	980168619.886	5.860	0.586	1.689	-65.138	-0.706	2.932	-2.955	32.547	-0.018	0.000	0.000	0.000	27.481769.344	-0.013	-13.670	51.010	0.000	0.000	0.000	100	0	
21	19:25:32	270	2021	980168620.256	6.085	0.608	1.697	-62.493	-0.717	2.963	-2.955	32.547	-0.018	0.000	0.000	0.000	27.494769.446	-0.013	-13.640	42.730	0.000	0.000	0.000	100	0	
22	19:55:32	270	2021	980168618.837	5.598	0.560	1.680	-58.458	-0.676	3.006	-2.955	32.547	-0.018	0.000	0.000	0.000	27.567769.590	-0.013	-16.730	45.310	0.000	0.000	0.000	100	0	
23	20:25:28	270	2021	980168620.172	6.193	0.622	1.702	-53.015	-0.587	3.057	-2.955	32.547	-0.018	0.000	0.000	0.000	27.609769.761	-0.013	-14.848	44.707	0.000	0.000	0.000	99	1	
24	20:55:32	270	2021	980168619.977	6.017	0.602	1.695	-46.159	-0.455	3.077	-2.955	32.547	-0.018	0.000	0.000	0.000	27.611769.825	-0.013	-15.160	38.640	0.000	0.000	0.000	100	0	
25	21:25:32	270	2021	980168620.015	5.571	0.557	1.679	-38.025	-0.289	3.065	-2.955	32.547	-0.018	0.000	0.000	0.000	27.555769.788	-0.013	-21.380	39.330	0.000	0.000	0.000	100	0	
26	21:55:32	270	2021	980168619.919	5.809	0.581	1.687	-28.764	-0.102	3.105	-2.955	32.547	-0.018	0.000	0.000	0.000	27.483769.921	-0.013	-27.590	45.310	0.000	0.000	0.000	100	0	
27	22:25:36	270	2021	980168620.290	5.295	0.532	1.671	-18.574	0.096	3.090	-2.955	32.547	-0.018	0.000	0.000	0.000	27.509769.869	-0.013	-26.778	44.000	0.000	0.000	0.000	99	1	
28	22:55:32	270	2021	980168619.759	5.532	0.553	1.678	-7.792	0.290	3.139	-2.955	32.547	-0.018	0.000	0.000	0.000	27.443770.032	-0.013	-32.840	45.390	0.000	0.000	0.000	100	0	
29	23:25:32	270	2021	980168619.315	5.267	0.527	1.670	3.334	0.467	3.178	-2.955	32.547	-0.018	0.000	0.000	0.000	27.496770.164	-0.013	-31.910	45.050	0.000	0.000	0.000	100	0	
30	23:55:32	270	2021	980168618.501	5.604	0.560	1.681	14.443	0.616	3.194	-2.955	32.547	-0.018	0.000	0.000	0.000	27.484770.217	-0.013	-28.110	49.510	0.000	0.000	0.000	100	0	
31	00:25:32	271	2021	980168619.657	5.304	0.530	1.671	25.181	0.728	3.196	-2.955	32.547	-0.018	0.000	0.000	0.000	27.515770.222	-0.013	-36.960	54.330	0.000	0.000	0.000	100	0	
32	00:55:47	271	2021	980168619.047	6.549	0.665	1.718	35.275	0.794	3.208	-2.955	32.547	-0.018	0.000	0.000	0.000	27.591770.264	-0.013	-32.423	57.608	0.000	0.000	0.000	97	3	
33	01:25:32	271	2021	980168619.216	5.465	0.547	1.676	44.159	0.809	3.221	-2.955	32.547	-0.018	0.000	0.000	0.000	27.579770.306	-0.013	-35.200	52.470	0.000	0.000	0.000	100	0	
34	01:55:36	271	2021	980168620.394	5.088	0.511	1.665	51.786	0.773	3.209	-2.955	32.547	-0.018	0.000	0.000	0.000	27.568770.265	-0.013	-37.535	52.848	0.000	0.000	0.000	99	1	
35	02:25:32	271	2021	980168618.607	5.933	0.593	1.692	57.782	0.689	3.181	-2.955	32.547	-0.018	0.000	0.000	0.000	27.604770.173	-0.013	-37.110	49.150	0.000	0.000	0.000	100	0	
36	02:55:32	271	2021	980168619.988	4.959	0.496	1.660	62.007	0.560	3.176	-2.955	32.547	-0.018	0.000	0.000	0.000	27.644770.156	-0.013	-36.930	50.040	0.000	0.000	0.000	100	0	
37	03:25:32	271	2021	980168619.333	6.030	0.603	1.695	64.326	0.395	3.202	-2.955	32.547	-0.018	0.000	0.000	0.000	27.676770.244	-0.013	-36.450	54.580	0.000	0.000	0.000	100	0	
38	03:55:32	271	2021	980168618.714	5.750	0.575	1.685	64.697	0.204	3.219	-2.955	32.547	-0.019	0.000	0.000	0.000	27.595770.300	-0.013	-39.290	49.320	0.000	0.000	0.000	100	0	
39	04:25:32	271	2021	980168617.346	6.206	0.621	1.702	63.153	-0.001	3.255	-2.955	32.547	-0.019	0.000	0.000	0.000	27.558770.421	-0.013	-38.910	47.340	0.000	0.000	0.000	100	0	
40	04:55:23	271	2021	980168616.008	17.198	1.765	2.371	59.821	-0.206	3.212	-2.955	32.547	-0.019	0.000	0.000	0.000	27.495770.277	-0.013	-41.568	43.768	0.000	0.000	0.000	95	5	
41	05:25:38	271	2021	980168619.147	5.528	0.558	1.680	54.788	-0.404	3.284	-2.955	32.547	-0.018	0.000	0.000	0.000	27.524770.517	-0.013	-41.816	45.663	0.000	0.000	0.000	98	2	
42	05:55:29	271	2021	980168618.769	5.616	0.564	1.682	48.416	-0.576	3.345	-2.955	32.547	-0.018	0.000	0.000	0.000	27.478770.719	-0.013	-38.657	49.192	0.000	0.000	0.000	99	1	
43	06:25:32	271	2021	980168618.369	6.231	0.623	1.702	40.854	-0.716	3.332	-2.955	32.547	-0.018	0.000	0.000	0.000	27.489770.678	-0.013	-32.330	40.300	0.000	0.000	0.000	100	0	
44	06:55:32	271	2021	980168617.849	6.949	0.695	1.730	32.449	-0.814	3.345	-2.955	32.547	-0.018	0.000	0.000	0.000	27.550770.718	-0.013	-37.210	41.410	0.000	0.000	0.000	100	0	
45	07:25:36	271	2021	980168619.240	5.993	0.602	1.695	23.471	-0.866	3.331	-2.955	32.547	-0.018	0.000	0.000	0.000	27.619770.673	-0.014	-36.424	45.071	0.000	0.000	0.000	99	1	

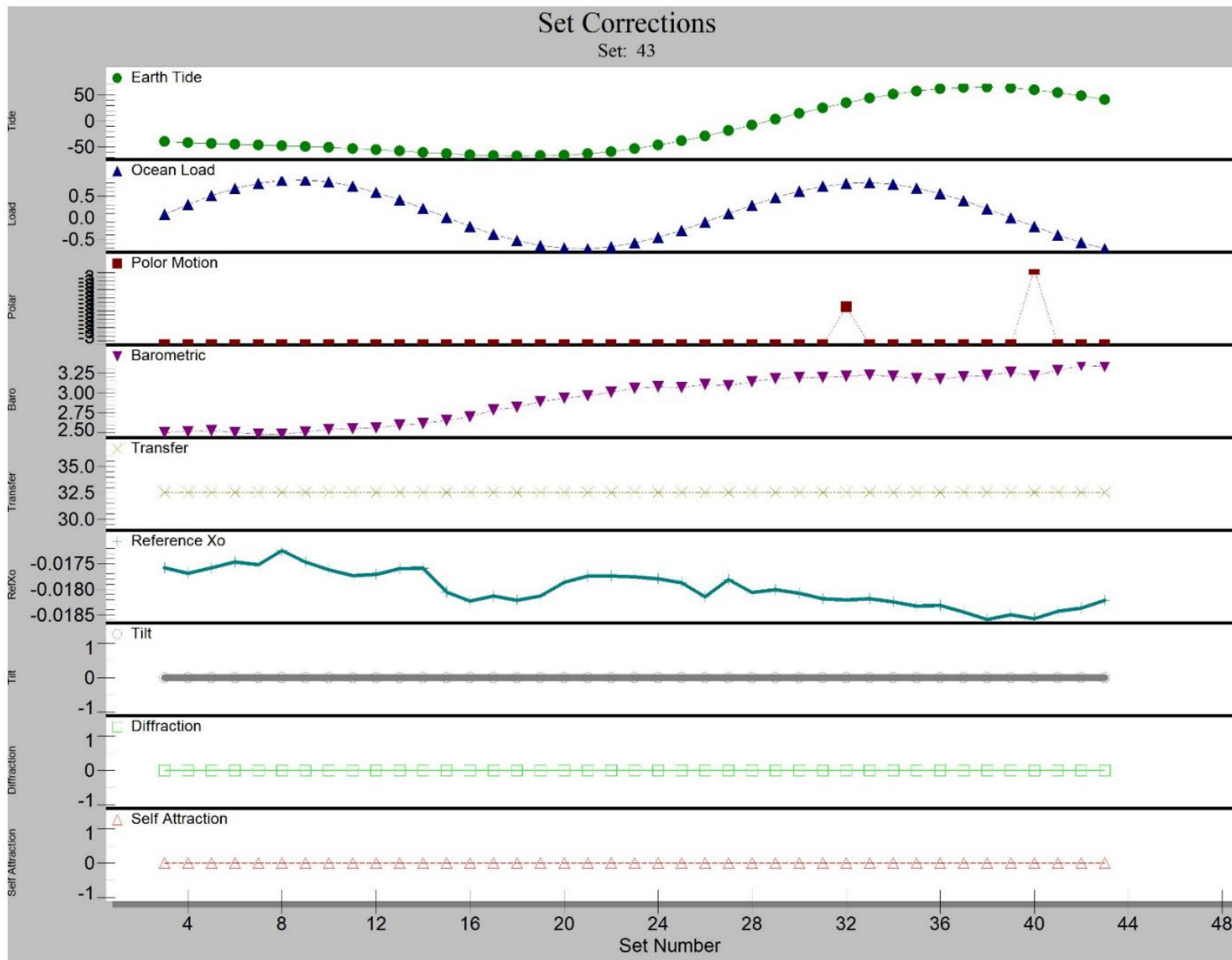




**Figure 2.** Plot of the set gravity values (1 set = 100 drops)



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



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