

# Absolute Gravity Measurement Campaign at Ross Island, Antarctica, 14-27 November 2018

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Technical Report by

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## Introduction

In this report we present absolute gravity measurements (AG) at Ross Island that took place 14th -27th November 2018. Measurements were done at three locations: SBG1, THIEL-1, and SBGR. The absolute gravity measurements were done with the FG5X-221 instrument owned by the Finnish Geospatial Research Institute (FGI) of the National Land Survey of Finland. The instrument was operated by Jyri Näränen from FGI. Absolute gravity measurements were done at the Metsähovi Geodetic Research Station (Southern Finland) directly before shipping the instrument to NZ and immediately upon return back. FGI has a dense time series of AG values at Metsähovi primary pillar since the fundamental gravity point of Finland is located at the station. The AG values measured at Metsähovi before and after (7<sup>th</sup> October 2018 and 17<sup>th</sup> January 2019) the Ross Island campaign were  $981916508.23 \pm 1.89 \mu\text{Gal}$  and  $981916508.36 \pm 2.20 \mu\text{Gal}$  respectively, measured on the same pillar and in the same orientation of the instrument. The values are very close to each other and indicate no change in instrument performance during the Antarctic campaign.

One possible source for error in AG measurements is the clock drift of the rubidium oscillator, i.e., the 10MHz frequency source of the instrument. In FG5X the Rb oscillator, located in the SIMx module, has the option of being GPS 1PPS controlled to exactly 10 MHz. During the Antarctic measurements reported here the GPS control worked at all the locations. As a sanity check, we also compared at each of the locations the SIMx Rb oscillator frequency to an external high-quality GPS controlled OCXO.

A developer version of the *g9* program was in use, which automatically zeroes the position of the absolute gravimeter superspring between sets. This removes the possibility of the spring drifting outside of optimal operating range due to, e.g., ambient temperature change.

Two of the sites (SBG1 and Thiel-1) had been previously occupied by FG5-228 (2009) and FG5-206 (2011 and 2015). During International Comparison of Absolute Gravimeters 2017, the difference between FG5-228 and FG5X-221 was found to be  $0.6 \mu\text{Gal}$  (FG5X-221 higher *g*), well within the uncertainty of the measurements. During the European Comparison of Absolute Gravimeters the preliminary difference (based on Draft A comparison report) between FG5-206 and FG5X-221 is  $5 \mu\text{Gal}$  (FG5X-221 higher *g*).

Each of the measurements reported here consist of 48 sets of 50 drops taken at 30 minute interval. Some additional sets were acquired at each of the sites but only 48 were used in the final calculation. 24 hour measurement time is required to minimize the possible diurnal ocean loading effects not compensated for completely by the *g9* program which uses global FES2004 model to correct for loading. Measurement heights on all the sites are relative to the highest point of the site marker. The same is assumed for the previous measurements at the sites, when comparing the measured gravity values. All times are in UTC. The orientation of the AG was magnetic south at Thiel-1 and SBG1 points and north at SBGR.

## Scott Base SBG1

### Absolute Gravity

Absolute gravity measurements were done with FGI's FG5-X #221. Measurements consist of 48 sets of 50 drops taken at 30 minute interval. 24 hour measurement time is required to minimize the possible diurnal ocean loading gravity effects not removed correctly by ocean loading modelling. Measurement heights are relative to the highest point of the site marker.

#### Gravity value at 100cm height

Gravity: **982977591.23  $\mu\text{Gal}$**

Set Scatter: 1.08  $\mu\text{Gal}$

Measurement Precision: 0.16  $\mu\text{Gal}$

Total Uncertainty: 2.13  $\mu\text{Gal}$

#### Gravity value at 0 cm height

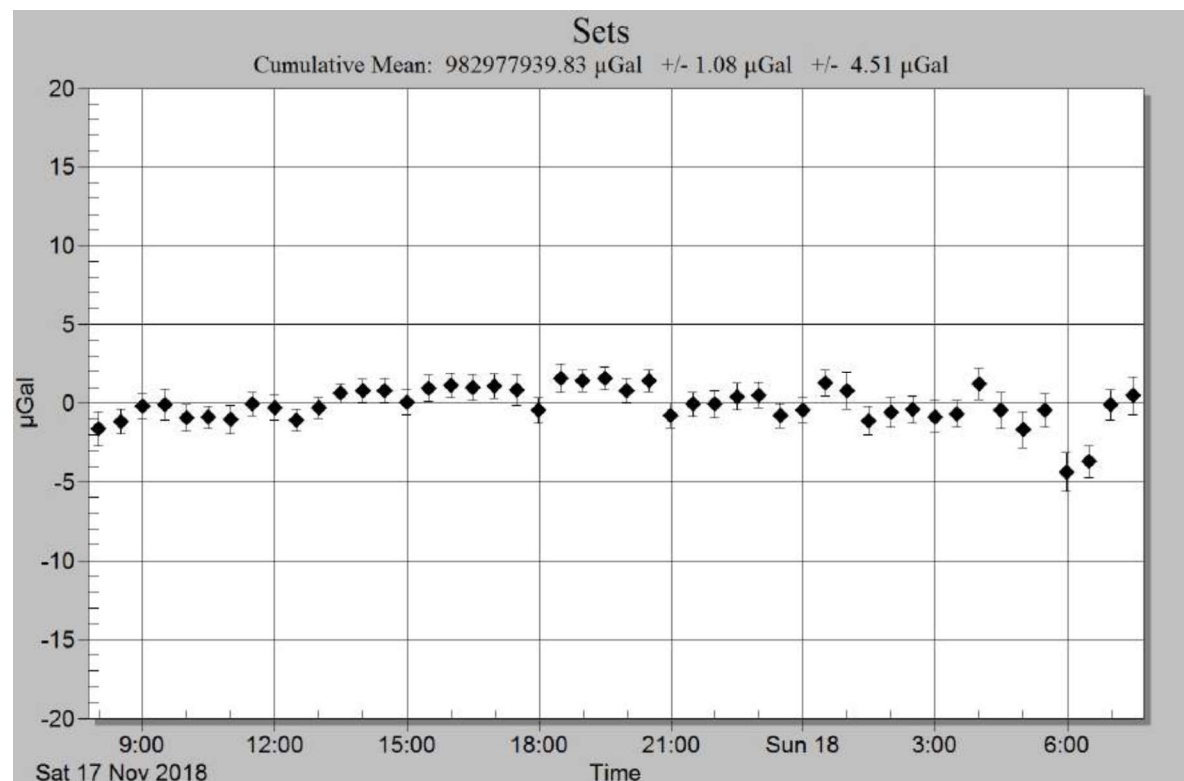
Gravity: **982977939.83  $\mu\text{Gal}$**

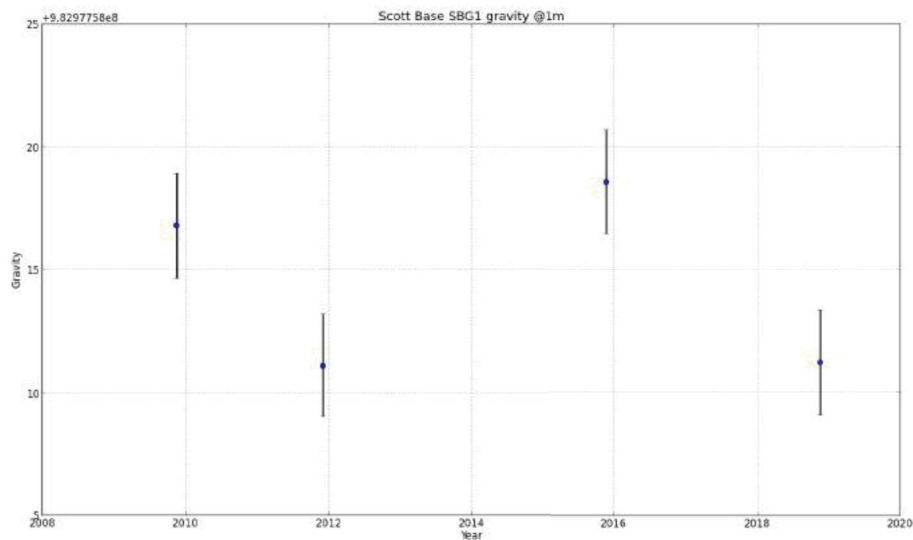
Set Scatter: 1.08  $\mu\text{Gal}$

Measurement Precision: 0.16  $\mu\text{Gal}$

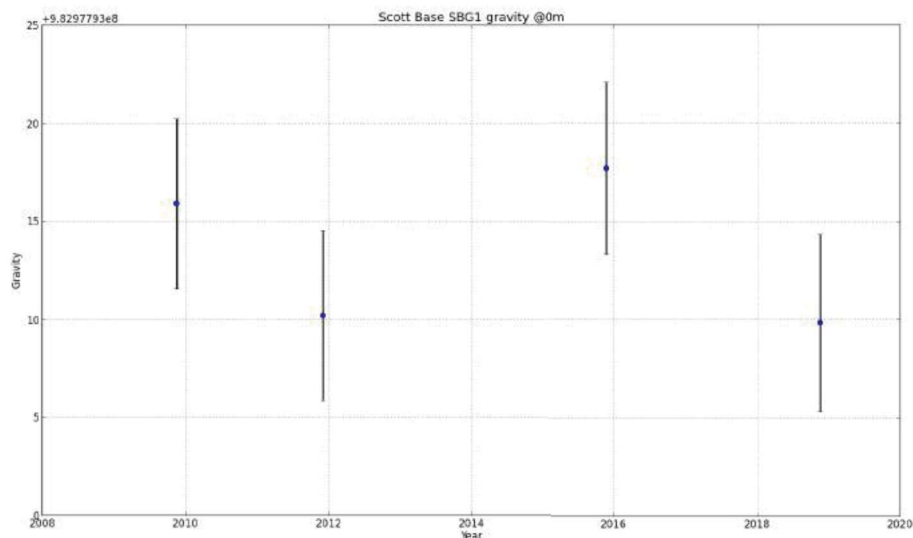
Total Uncertainty: 4.51  $\mu\text{Gal}$

The total uncertainty of gravity value is conservative as the *g9* program used for the absolute gravity calculation uses a fixed uncertainty of 3  $\mu\text{Gal}/\text{m}$  for vertical gradient of gravity. As can be seen below, a lower uncertainty for the measured value is given.





SBG1 absolute gravity values at 1-meter height.



SBG1 Absolute gravity values at top of the marker. The bigger uncertainty than at one meter level is due to the uncertainty in the vertical gradient of gravity. In reality they are likely smaller since the *g9* program is conservative in gradient measurement uncertainties.

### Gravity Gradient

Vertical gradient of gravity was measured with Scintrex CG-5 #052 relative gravimeter. Measurements were done at three heights to investigate the possible nonlinearity/pillar effect of the gradient. Heights were chosen to be close to the start of FG5-X drop, effective height of A10, and as close to the pillar as possible. Measurement was a loop measurement consisting of six loops, 18 height station occupations in total. At each station, three one minute measurements were required to be within three  $\mu\text{Gal}$  before moving to the next station. This ensured

that the measurements were done at the same part of the drift curve of the Scintrex gravimeter, which is slightly nonlinear some minutes after movement. The values used for the gradient calculation were averages of these three one minute measurements. Gravimeter drift as well as tidal effects were removed in the calculation and a network adjustment was performed.

Station heights:

SBG1H	1287,3	mm
SBG1M	839,7	mm
SBG1L	123	mm

Gradient ( $\mu\text{Gal}/\text{m}$ )

SBG1H->SBG1L	348,6 $\pm 1,5\mu\text{Gal}/\text{m}$
SBG1H->SBG1M	349,9 $\pm 1,5\mu\text{Gal}/\text{m}$
SBG1M->SBG1L	347,8 $\pm 1,5\mu\text{Gal}/\text{m}$

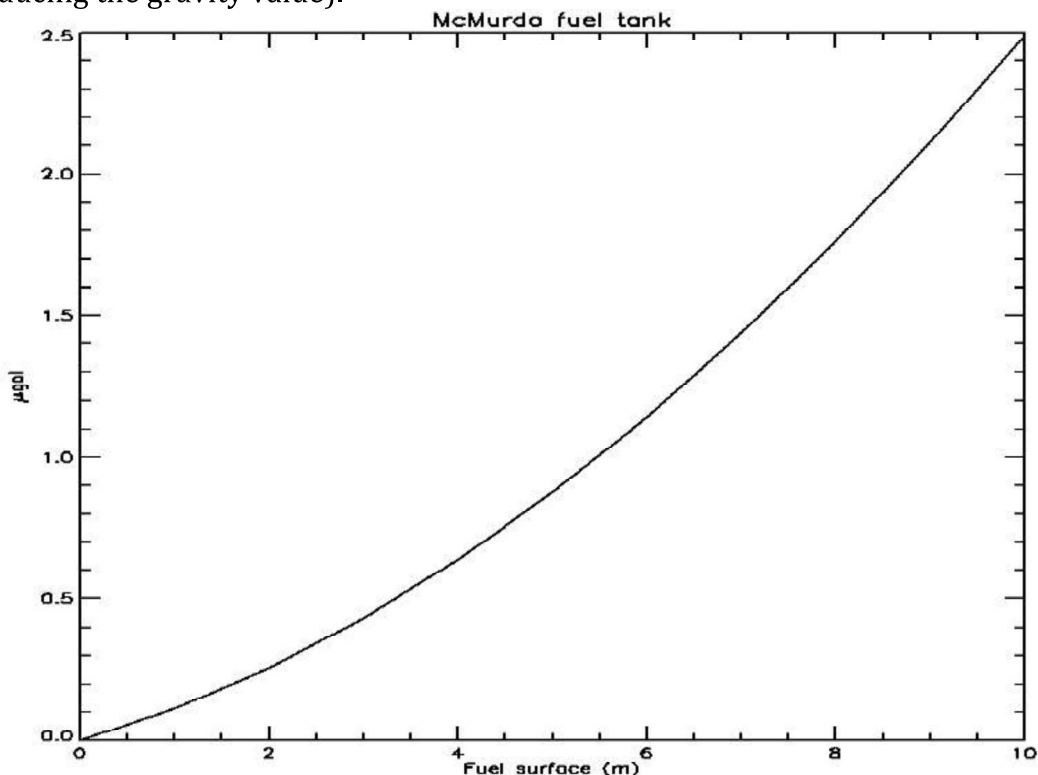
Slight nonlinearity is present, but for the purpose of this paper we use the value **-348,6  $\mu\text{Gal}/\text{m}$**  in the AG measurement calculations as well as when providing the gravity values at height of one meter above the reference marker and at the reference marker. This value is within the error margin of the gradient value -349.1 $\pm 3$   $\mu\text{Gal}/\text{m}$  used in previous reports.

## McMurdo Thiel-1

### Absolute Gravity

See general comments above.

The fuel tank T-1 had 426 242 gallons (@60F/15.6C net) of fuel at the time of the measurements. Gross volume at 10F/-12C is 415 319 gallons. Information was received on Nov 16th from Fuels Supervisor Chad Goodale (McMurdo). In 2009 campaign report by Rogister *et al.* a formulae for calculating the direct attraction of the fuel to the Thiel-1 point are given. They calculate the maximum gravity effect of the ~2 million gallon container to be approximately 2  $\mu\text{Gal}$  in vertical direction. Since the tank was approximately one-fifth full at the time of the measurements, the effect of fuel to the measured absolute gravity was less than 0.5  $\mu\text{Gal}$  (reducing the gravity value).



The same can be observed in the plot above, which was produced from numerical analysis of the gravity effect based on the initial dimensions and distances reported in the 2009 measurement report by Rogister *et al.*

NOTE: While the site is very quiet microseismically, the pillar seems to be somewhat unstable. Measured with the tilt meters of Scintrex CG-5 relative gravimeter the pillar can tilt by approximately 20 arcseconds when one steps on it and even walking in the hut introduces tilts of one to two arcseconds. Since operators are not present for most of the time during absolute gravity measurements this should not be a large issue. However some uncertainty remains in the verticality of the absolute gravimeter.

### Gravity value at 100cm height

Gravity: **982970228.50  $\mu\text{Gal}$**

Set Scatter: 1.28  $\mu\text{Gal}$

Measurement Precision: 0.18  $\mu\text{Gal}$

Total Uncertainty: 2.15  $\mu\text{Gal}$

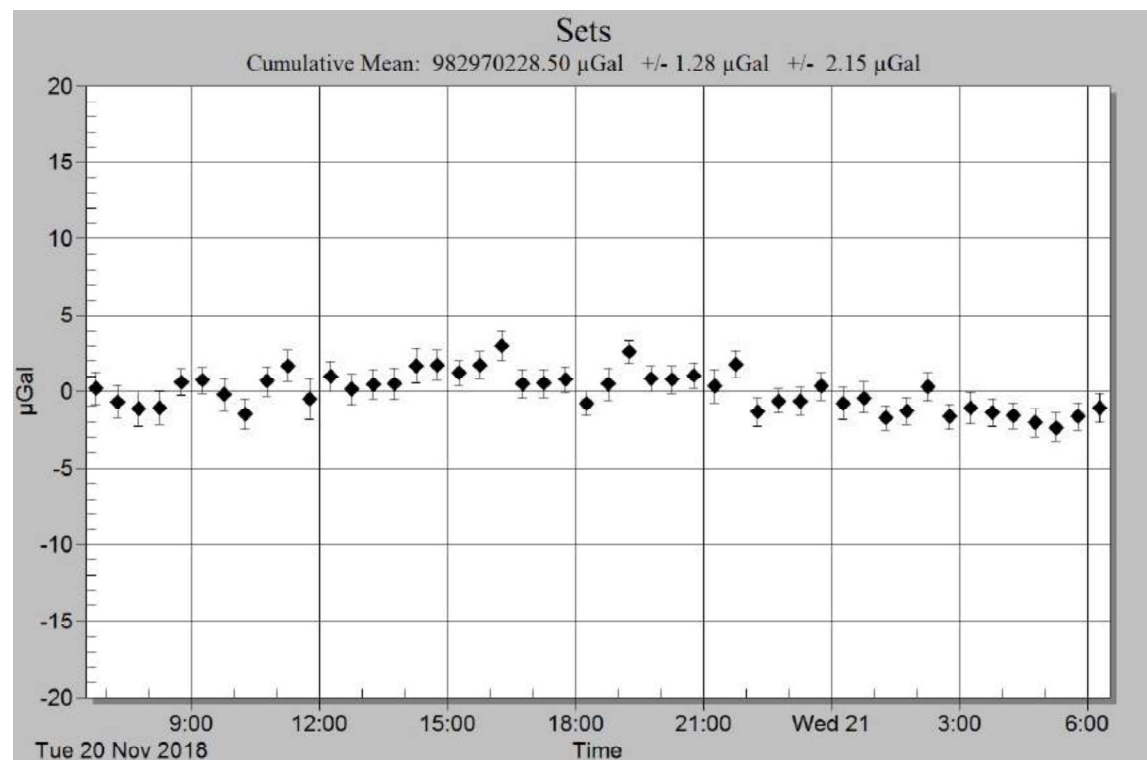
### Gravity value at 0 cm height

Gravity: **982970539.70  $\mu\text{Gal}$**

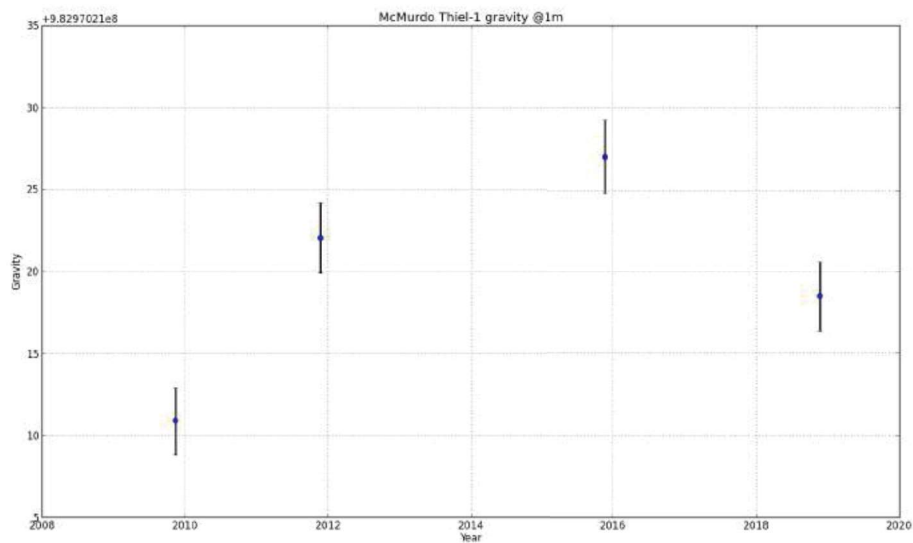
Set Scatter: 1.28  $\mu\text{Gal}$

Measurement Precision: 0.18  $\mu\text{Gal}$

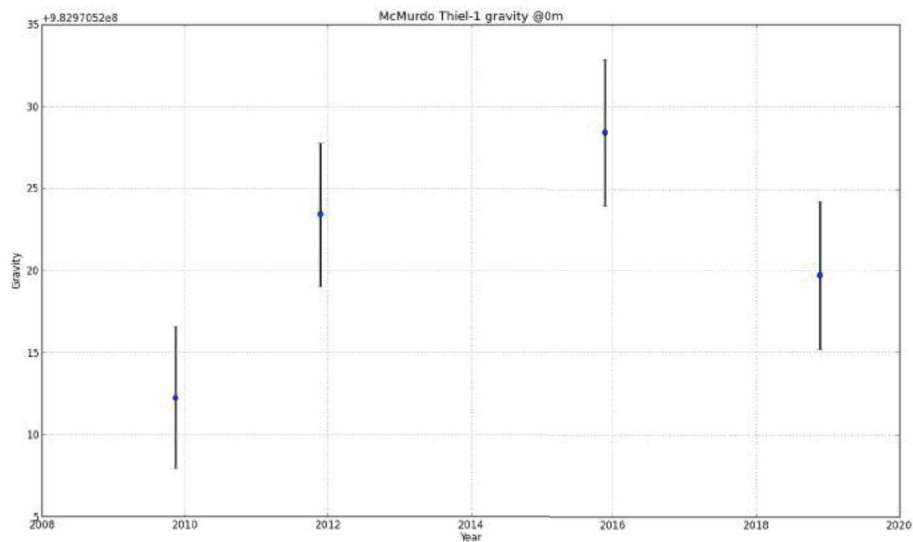
Total Uncertainty: 4.53  $\mu\text{Gal}$



The average gravity values of the 48 sets of 50 drops each used in the final calculation of the absolute gravity value.



Thiel-1 absolute gravity values at 1-meter height.



Thiel-1 Absolute gravity values at top of the marker. The bigger uncertainty than at one meter level is due to the uncertainty in the vertical gradient of gravity. In reality they are likely smaller since the *g9* program is conservative in gradient measurement uncertainties.

### Gravity Gradient

See general comments above.

Station heights

ThielH	1301,3	mm
ThielM	801,7	mm
ThielL	128,5	mm

Gradient (μGal/m)

ThielH->ThielL	311,2	$\pm 1,5\mu\text{Gal}$
ThielH->ThielM	300,4	$\pm 1,5\mu\text{Gal}$
ThielM->ThielL	319,2	$\pm 1,5\mu\text{Gal}$

Nonlinearity is present, but for the purpose of this paper we use the value **-311,2  $\mu\text{Gal}/\text{m}$**  in the AG measurement calculations as well as when providing the gravity values at height of one meter above the reference marker and at the reference marker.

## Crater Hill SBGR

### Absolute Gravity

See general comments above.

#### Gravity value at 100cm height

Gravity: **982938130.27  $\mu\text{Gal}$**

Set Scatter: 1.94  $\mu\text{Gal}$

Measurement Precision: 0.28  $\mu\text{Gal}$

Total Uncertainty: 2.18  $\mu\text{Gal}$

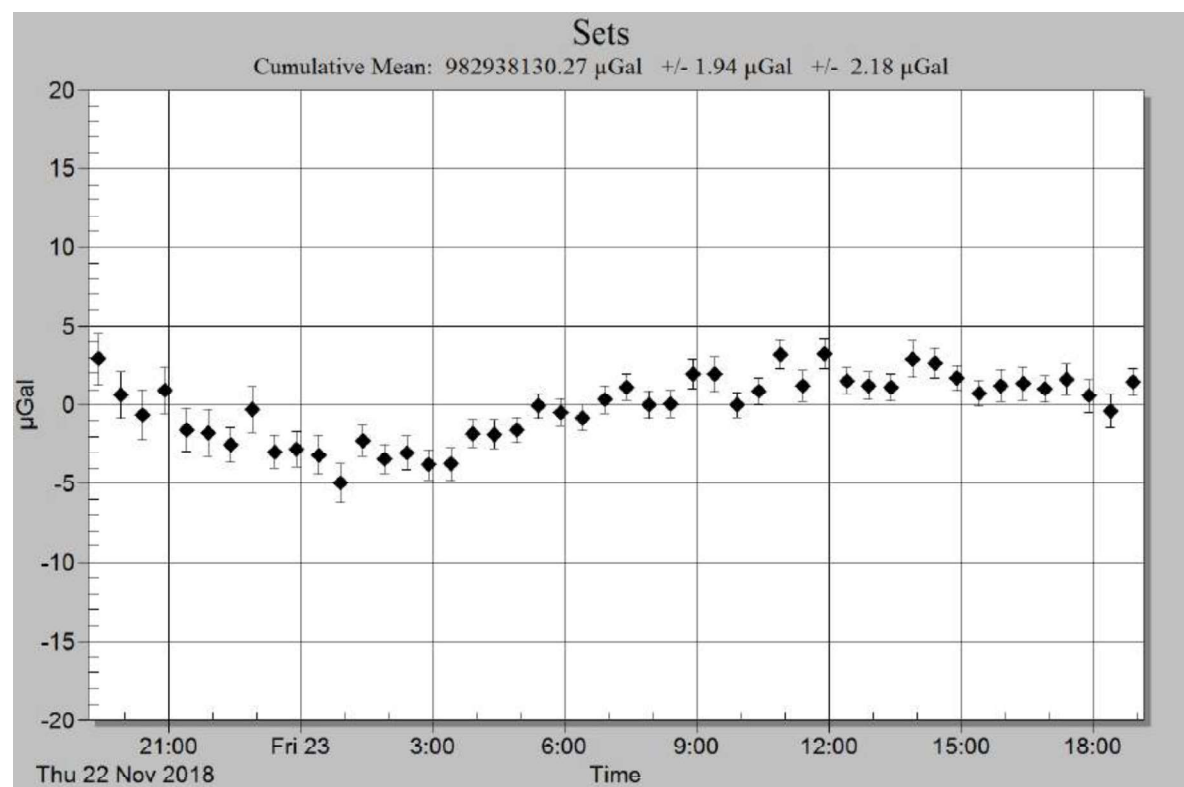
#### Gravity value at 0 cm height

Gravity: **982938516.37  $\mu\text{Gal}$**

Set Scatter: 1.94  $\mu\text{Gal}$

Measurement Precision: 0.28  $\mu\text{Gal}$

Total Uncertainty: 4.55  $\mu\text{Gal}$



The average gravity values of the 48 sets of 50 drops each used in the final calculation of the absolute gravity value. Notice the waveform in the gravity measurements, that is due to FES2004 ocean loading model not working perfectly at this site.

### Gravity Gradient

See general comments above.

Station heights

SBGRH	1298,8	mm
SBGRM	803,2	mm
SBGRL	128,5	mm

Gradient ( $\mu\text{Gal}/\text{m}$ )

SBGRH->SBGRL	386,1	$\pm 1,5\mu\text{Gal}$
SBGRH->SBGRM	383,5	$\pm 1,5\mu\text{Gal}$
SBGRM->SBGRL	388,0	$\pm 1,5\mu\text{Gal}$

Slight nonlinearity is present, but for the purpose of this paper we use the value **-386,1  $\mu\text{Gal}/\text{m}$**  in the AG measurement calculations as well as when providing the gravity values at height of one meter above the reference marker and at the reference marker.

## Appendix 1

### Set processing log for AG measurements

#### Scott Base SBG1

100 cm height

0 cm height

Micro-g LaCoste g Processing Report

File Created: 12/14/18, 12:43:49

Project Name: 2018\_11\_17\_100cm

g Acquisition Version: 4.041600

g Processing Version: 9.120423

Company/Institution: FGI

Operator: JN

Station Data

Name: Scott Base

Site Code: AA

Lat: -77.84890 Long: 166.76910 Elev: 9.10 m

Setup Height: 11.70 cm

Transfer Height: 100.00 cm

Transfer Height: 0.00 cm

Actual Height: 137.50 cm

Gradient: -3.486  $\mu$ Gal/cm

Nominal Air Pressure: 1012.16 mBar

Barometric Admittance Factor: 0.30

Polar Motion Coord: 0.1681 " 0.2798 "

Earth Tide (ETGTAB) Selected

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

Delta Factor Filename: C:\Users\admin\Desktop\Scott Base\OceanLoad-Scott Base.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:\Users\admin\Desktop\Scott Base\OceanLoad-  
Scott Base.olf  
Waves: M2 S2 K1 O1 N2 P1 K2 Q1 Mf Mm Ssa  
Amplitude (μGal): 0.486 0.159 2.746 2.247 0.122 0.912 0.063 0.475 0.000  
0.000 0.000  
Phase (deg): -227.4 -200.2 -167.8 -157.2 -193.9 -167.9 -198.5 -152.3 0.0 0.0  
0.0

Instrument Data  
Meter Type: FG5  
Meter S/N: 221  
Factory Height: 125.80 cm  
Rubidium Frequency: 10000000.00000 Hz  
Laser: WEO100 (197)  
ID: 632.99117754 nm ( 1.15 V)  
IE: 632.99119473 nm ( 0.76 V)  
IF: 632.99121259 nm ( 0.42 V)  
IG: 632.99123023 nm ( 0.10 V)  
IH: 632.99136890 nm ( -0.95 V)  
II: 632.99139822 nm ( -0.96 V)  
IJ: 632.99142704 nm ( -1.02 V)  
Modulation Frequency: 8333.330 Hz

Processing Results  
Date: 11/17/18  
Time: 19:44:35  
DOY: 321  
Year: 2018  
Time Offset (D h:m:s): 0 0:0:0  
Gravity: 982977591.23 μGal  
Gravity: 982977939.83 μGal  
Set Scatter: 1.08 μGal  
Measurement Precision: 0.16 μGal  
Total Uncertainty: 2.13 μGal  
Total Uncertainty: 4.51 μGal  
Number of Sets Collected: 71  
Number of Sets Processed: 48  
Set #s Processed:  
1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,  
31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48  
Number of Sets NOT Processed: 23  
Set #s NOT Processed:  
49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71  
Number of Drops/Set: 50  
Total Drops Accepted: 2395  
Total Drops Rejected: 5  
Total Fringes Acquired: 1150

Fringe Start: 12  
Processed Fringes: 795  
GuideCard Multiplex: 4  
GuideCard Scale Factor: 300

Acquisition Settings  
Set Interval: 30 min  
Drop Interval: 10 sec  
Number of Sets: 480  
Number of Drops: 50

Gravity Corrections  
Earth Tide (ETGTAB): -61.26  $\mu\text{Gal}$   
Ocean Load: -0.06  $\mu\text{Gal}$   
Polar Motion: -1.79  $\mu\text{Gal}$   
Barometric Pressure: -7.41  $\mu\text{Gal}$   
**Transfer Height: 130.73  $\mu\text{Gal}$**   
**Transfer Height: 479.33  $\mu\text{Gal}$**   
Reference Xo: -0.02  $\mu\text{Gal}$   
Diffraction: 1.40  $\mu\text{Gal}$   
Self Attraction: -1.17  $\mu\text{Gal}$

Uncertainties  
Sigma Reject: 3.00  
Earth Tide Factor: 0.001  
Average Earth Tide Uncertainty: 0.06  $\mu\text{Gal}$   
Ocean Load Factor: 0.10  
Average Ocean Load Uncertainty: 0.01  $\mu\text{Gal}$   
Barometric: 1.00  $\mu\text{Gal}$   
Polar Motion: 0.05  $\mu\text{Gal}$   
Laser: 0.01  $\mu\text{Gal}$   
Clock: 0.50  $\mu\text{Gal}$   
System Type: 1.00  $\mu\text{Gal}$   
Tidal Swell: 0.00  $\mu\text{Gal}$   
Water Table: 0.00  $\mu\text{Gal}$   
Unmodeled: 0.00  $\mu\text{Gal}$   
System Setup: 1.00  $\mu\text{Gal}$   
**Gradient: 1.125  $\mu\text{Gal}$  (0.030  $\mu\text{Gal}/\text{cm}$ )**  
**Gradient: 4.125  $\mu\text{Gal}$  (0.030  $\mu\text{Gal}/\text{cm}$ )**

## McMurdo Base Thiel-1

**100 cm height**

**0 cm height**

Micro-g LaCoste g Processing Report

File Created: 12/14/18, 13:37:21

Project Name: 2018\_11\_20\_100cm

g Acquisition Version: 4.041600

g Processing Version: 9.120423

Company/Institution: FGI

Operator: JN

### Station Data

Name: McMurdo

Site Code: Thiel-1

Lat: -77.84900 Long: 166.67940 Elev: 46.21 m

Setup Height: 12.30 cm

**Transfer Height: 100.00 cm**

**Transfer Height: 0.00 cm**

Actual Height: 138.10 cm

Gradient: -3.112  $\mu$ Gal/cm

Nominal Air Pressure: 1007.71 mBar

Barometric Admittance Factor: 0.30

Polar Motion Coord: 0.1650 " 0.2783 "

Earth Tide (ETGTAB) Selected

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

Delta Factor Filename: C:\Users\admin\Desktop\McMurdo\OceanLoad-McMurdo.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:\Users\admin\Desktop\McMurdo\OceanLoad-McMurdo.olf

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

Amplitude ( $\mu\text{Gal}$ ): 0.496 0.159 2.785 2.278 0.121 0.925 0.064 0.482 0.000  
0.000 0.000  
Phase (deg): -226.3 -198.0 -168.1 -157.6 -193.1 -168.2 -196.6 -152.6 0.0 0.0  
0.0

#### Instrument Data

Meter Type: FG5  
Meter S/N: 221  
Factory Height: 125.80 cm  
Rubidium Frequency: 10000000.00000 Hz  
Laser: WEO100 (197)  
ID: 632.99117754 nm ( 1.15 V)  
IE: 632.99119473 nm ( 0.76 V)  
IF: 632.99121259 nm ( 0.42 V)  
IG: 632.99123023 nm ( 0.10 V)  
IH: 632.99136890 nm ( -0.95 V)  
II: 632.99139822 nm ( -0.96 V)  
IJ: 632.99142704 nm ( -1.02 V)  
Modulation Frequency: 8333.330 Hz

#### Processing Results

Date: 11/20/18  
Time: 18:30:32  
DOY: 324  
Year: 2018  
Time Offset (D h:m:s): 0 0:0:0  
Gravity: 982970228.50  $\mu\text{Gal}$   
Gravity: 982970539.70  $\mu\text{Gal}$   
Set Scatter: 1.28  $\mu\text{Gal}$   
Measurement Precision: 0.18  $\mu\text{Gal}$   
Total Uncertainty: 2.15  $\mu\text{Gal}$   
Total Uncertainty: 4.53  $\mu\text{Gal}$   
Number of Sets Collected: 75  
Number of Sets Processed: 48  
Set #s Processed:  
1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,  
31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48  
Number of Sets NOT Processed: 27  
Set #s NOT Processed:  
49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,  
75  
Number of Drops/Set: 50  
Total Drops Accepted: 2398  
Total Drops Rejected: 2  
Total Fringes Acquired: 1150  
Fringe Start: 12  
Processed Fringes: 795  
GuideCard Multiplex: 4  
GuideCard Scale Factor: 300

#### Acquisition Settings

Set Interval: 30 min

Drop Interval: 10 sec

Number of Sets: 480

Number of Drops: 50

#### Gravity Corrections

Earth Tide (ETGTAB): -65.59  $\mu\text{Gal}$

Ocean Load: 0.11  $\mu\text{Gal}$

Polar Motion: -1.77  $\mu\text{Gal}$

Barometric Pressure: -11.31  $\mu\text{Gal}$

Transfer Height: 118.57  $\mu\text{Gal}$

Transfer Height: 429.77  $\mu\text{Gal}$

Reference Xo: -0.02  $\mu\text{Gal}$

Diffraction: 1.40  $\mu\text{Gal}$

Self Attraction: -1.17  $\mu\text{Gal}$

#### Uncertainties

Sigma Reject: 3.00

Earth Tide Factor: 0.001

Average Earth Tide Uncertainty: 0.07  $\mu\text{Gal}$

Ocean Load Factor: 0.10

Average Ocean Load Uncertainty: 0.01  $\mu\text{Gal}$

Barometric: 1.00  $\mu\text{Gal}$

Polar Motion: 0.05  $\mu\text{Gal}$

Laser: 0.01  $\mu\text{Gal}$

Clock: 0.50  $\mu\text{Gal}$

System Type: 1.00  $\mu\text{Gal}$

Tidal Swell: 0.00  $\mu\text{Gal}$

Water Table: 0.00  $\mu\text{Gal}$

Unmodeled: 0.00  $\mu\text{Gal}$

System Setup: 1.00  $\mu\text{Gal}$

Gradient: 1.143  $\mu\text{Gal}$  (0.030  $\mu\text{Gal}/\text{cm}$ )

Gradient: 4.143  $\mu\text{Gal}$  (0.030  $\mu\text{Gal}/\text{cm}$ )

## Crater Hill SBGR

**100 cm height**

**0 cm height**

Micro-g LaCoste g Processing Report

File Created: 12/14/18, 14:34:15

Project Name: 2018\_11\_22\_100cm

g Acquisition Version: 4.041600

g Processing Version: 9.120423

Company/Institution: FGI

Operator: JN

### Station Data

Name: Crater Hill

Site Code: SBGR

Lat: -77.84481 Long: 166.72631 Elev: 190.89 m

Setup Height: 12.55 cm

**Transfer Height: 100.00 cm**

**Transfer Height: 0.00 cm**

Actual Height: 138.35 cm

Gradient: -3.861  $\mu$ Gal/cm

Nominal Air Pressure: 990.53 mBar

Barometric Admittance Factor: 0.30

Polar Motion Coord: 0.1629 " 0.2777 "

Earth Tide (ETGTAB) Selected

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

Delta Factor Filename: C:\Users\admin\Desktop\Crater Hill\OceanLoad-Crater Hill.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:\Users\admin\Desktop\Crater Hill\OceanLoad-Crater Hill.olf

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

Amplitude ( $\mu\text{Gal}$ ): 0.537 0.162 2.967 2.427 0.122 0.986 0.065 0.515 0.000  
0.000 0.000  
Phase (deg): -222.9 -190.6 -169.2 -158.8 -190.9 -169.3 -190.2 -153.8 0.0 0.0  
0.0

#### Instrument Data

Meter Type: FG5  
Meter S/N: 221  
Factory Height: 125.80 cm  
Rubidium Frequency: 10000000.00000 Hz  
Laser: WEO100 (197)  
ID: 632.99117754 nm ( 1.06 V)  
IE: 632.99119473 nm ( 0.70 V)  
IF: 632.99121259 nm ( 0.38 V)  
IG: 632.99123023 nm ( 0.07 V)  
IH: 632.99136890 nm ( -0.94 V)  
II: 632.99139822 nm ( -0.96 V)  
IJ: 632.99142704 nm ( -1.01 V)  
Modulation Frequency: 8333.330 Hz

#### Processing Results

Date: 11/23/18  
Time: 07:09:16  
DOY: 327  
Year: 2018  
Time Offset (D h:m:s): 0 0:0:0  
Gravity: 982938130.27  $\mu\text{Gal}$   
Gravity: 982938516.37  $\mu\text{Gal}$   
Set Scatter: 1.94  $\mu\text{Gal}$   
Measurement Precision: 0.28  $\mu\text{Gal}$   
Total Uncertainty: 2.18  $\mu\text{Gal}$   
Total Uncertainty: 4.55  $\mu\text{Gal}$   
Number of Sets Collected: 79  
Number of Sets Processed: 48  
Set #s Processed:  
32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,  
58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79  
Number of Sets NOT Processed: 31  
Set #s NOT Processed:  
1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,  
31  
Number of Drops/Set: 50  
Total Drops Accepted: 2397  
Total Drops Rejected: 3  
Total Fringes Acquired: 1150  
Fringe Start: 12  
Processed Fringes: 795  
GuideCard Multiplex: 4  
GuideCard Scale Factor: 300

#### Acquisition Settings

Set Interval: 30 min

Drop Interval: 10 sec

Number of Sets: 480

Number of Drops: 50

#### Gravity Corrections

Earth Tide (ETGTAB): -58.48  $\mu\text{Gal}$

Ocean Load: -0.23  $\mu\text{Gal}$

Polar Motion: -1.75  $\mu\text{Gal}$

Barometric Pressure: -8.31  $\mu\text{Gal}$

Transfer Height: 148.07  $\mu\text{Gal}$

Transfer Height: 534.17  $\mu\text{Gal}$

Reference Xo: -0.03  $\mu\text{Gal}$

Diffraction: 1.40  $\mu\text{Gal}$

Self Attraction: -1.17  $\mu\text{Gal}$

#### Uncertainties

Sigma Reject: 3.00

Earth Tide Factor: 0.001

Average Earth Tide Uncertainty: 0.06  $\mu\text{Gal}$

Ocean Load Factor: 0.10

Average Ocean Load Uncertainty: 0.02  $\mu\text{Gal}$

Barometric: 1.00  $\mu\text{Gal}$

Polar Motion: 0.05  $\mu\text{Gal}$

Laser: 0.01  $\mu\text{Gal}$

Clock: 0.50  $\mu\text{Gal}$

System Type: 1.00  $\mu\text{Gal}$

Tidal Swell: 0.00  $\mu\text{Gal}$

Water Table: 0.00  $\mu\text{Gal}$

Unmodeled: 0.00  $\mu\text{Gal}$

System Setup: 1.00  $\mu\text{Gal}$

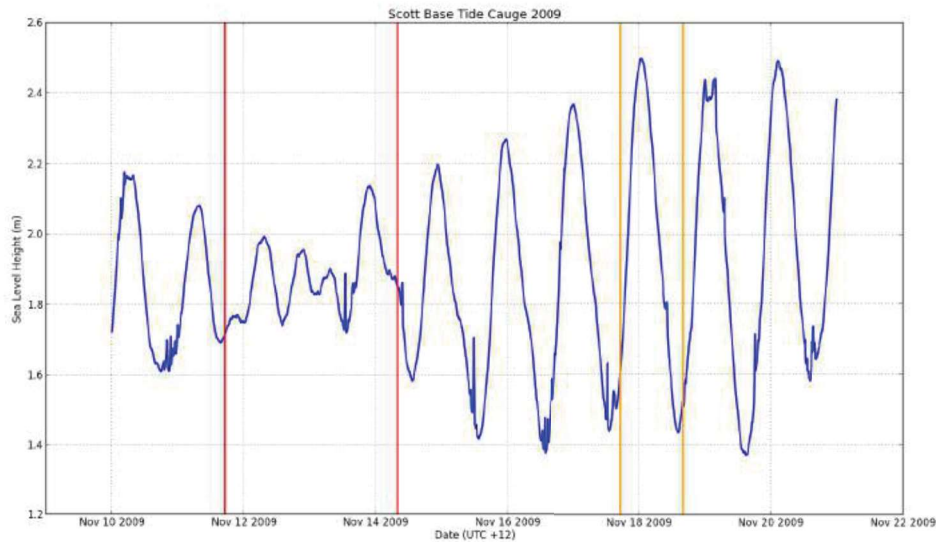
Gradient: 1.150  $\mu\text{Gal}$  (0.030  $\mu\text{Gal}/\text{cm}$ )

Gradient: 4.151  $\mu\text{Gal}$  (0.030  $\mu\text{Gal}/\text{cm}$ )

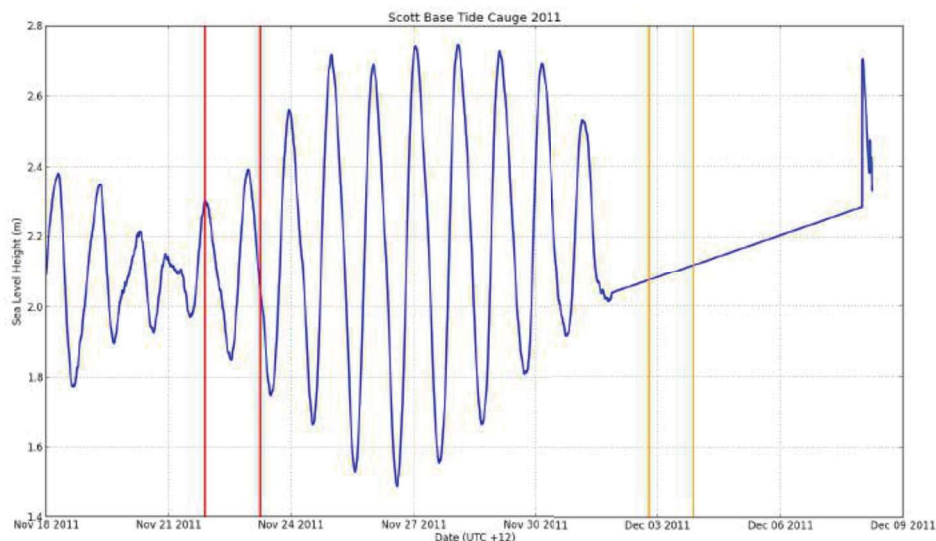
## Appendix 2

### Tide gauge data

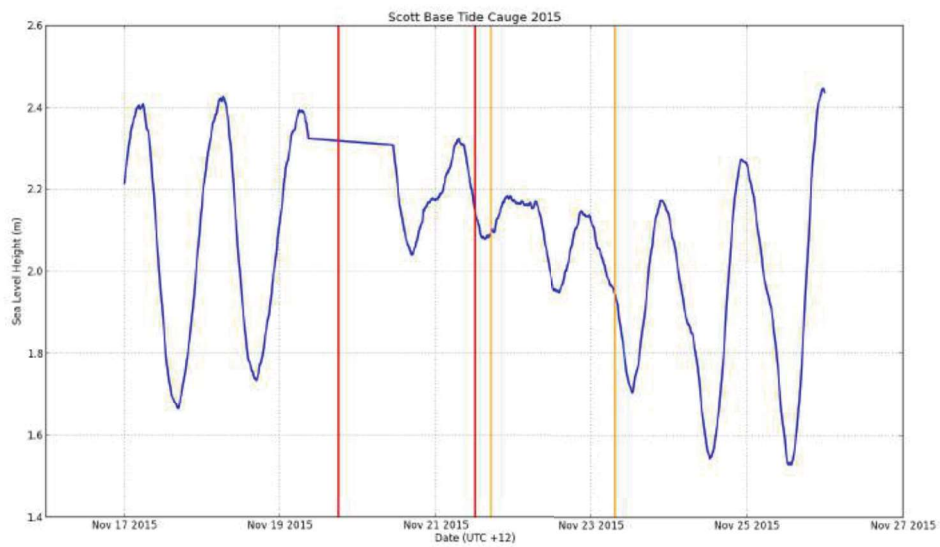
As all three measurement sites are located on an island and close to the sea, it is important to assess the potential effect of tidal and nontidal loading effects of the nearby sea to the gravity data. Towards this end we obtained the Scott Base tide gauge data for all the measurement epochs.



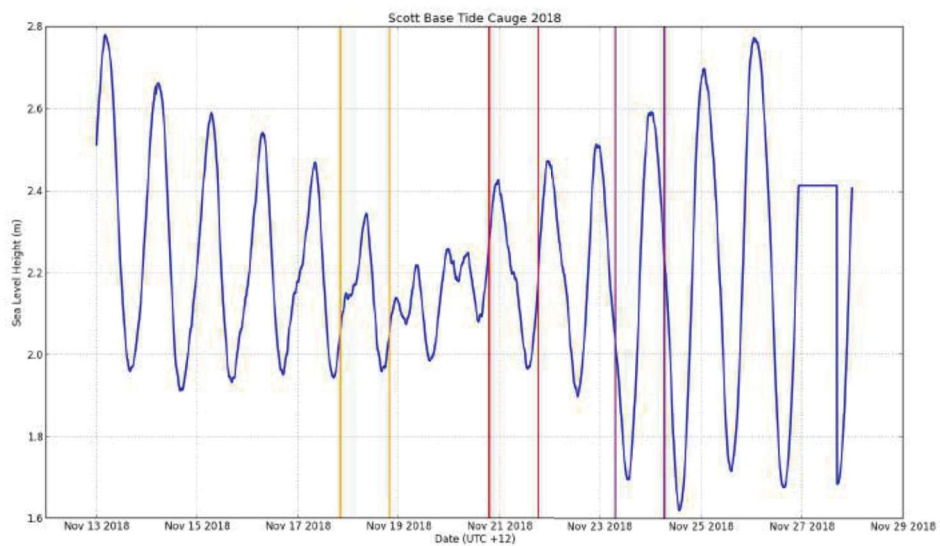
Scott Base tide gauge data and the AG measurement times for the 2009 campaign indicated (red Thiel-1, yellow SBG-1).



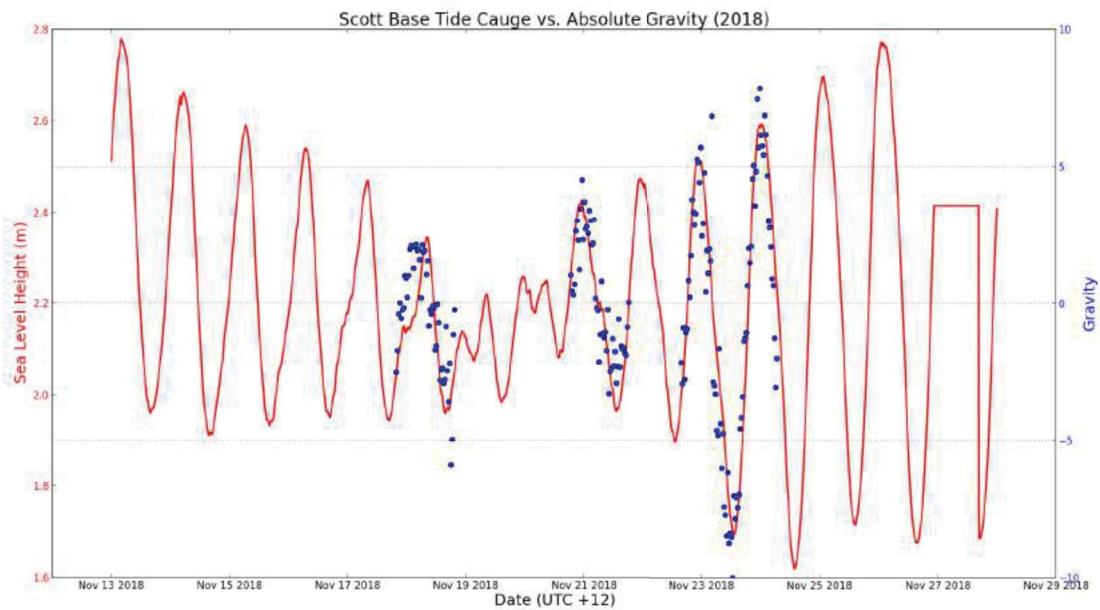
Scott Base tide gauge data and the AG measurement times for the 2011 campaign indicated (red Thiel-1, yellow SBG-1). Unfortunately no data is available during the time of SBG-1 measurements.



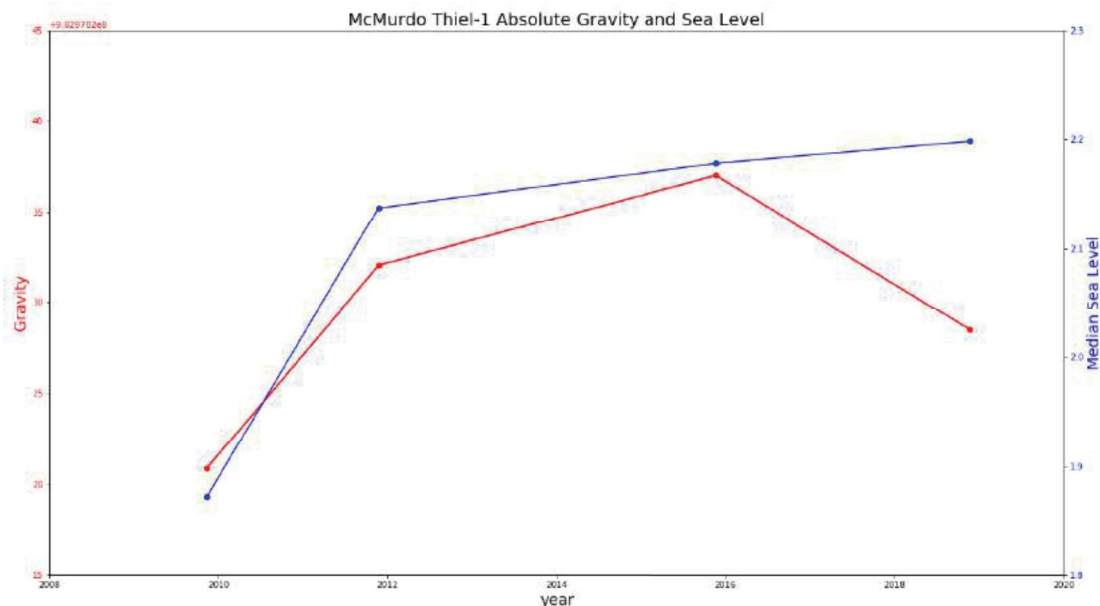
Scott Base tide gauge data and the AG measurement times for the 2015 campaign indicated (red Thiel-1, yellow SBG-1). Some data is missing dueing the Thiel-1 measurements.

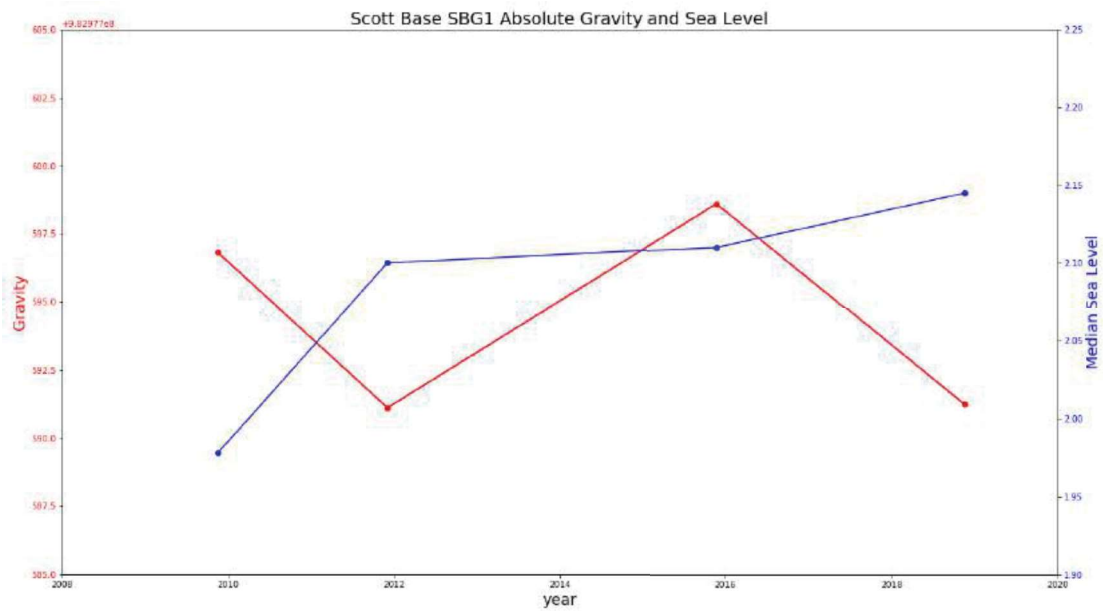


Scott Base tide gauge data and the AG measurement times for the 2009 campaign indicated (red Thiel-1, yellow SBG-1, and purple SBGR).



In this plot, all set averages from the three site occupations during the 2018 measurement campaign are compared to the tide gauge values. Loading correction has been turned off in the *g9* calculation for these set averages. Gravity values are normalized to the final gravity value at each site. It is obvious that there is a correlation between the sea height and the gravity value. This is of course to be expected, the main purpose here was to emphasize the importance of using  $n \times 24\text{h}$  time frames when calculating the final *g* value since the modelling of loading effects in *g9* program is not perfect as can be seen in, e.g., the set gravity plot from Crater Hill site in this report. Failing to do so can lead to unwanted bias in the final value.





In the above two pictures the median sea level during gravity measurements is compared with the gravity value. Since the gravity points are so close the sea, it is plausible that there could be nontidal loading effects in gravity. No clear correlation between sea level and measured gravity values is found.

## Appendix 3

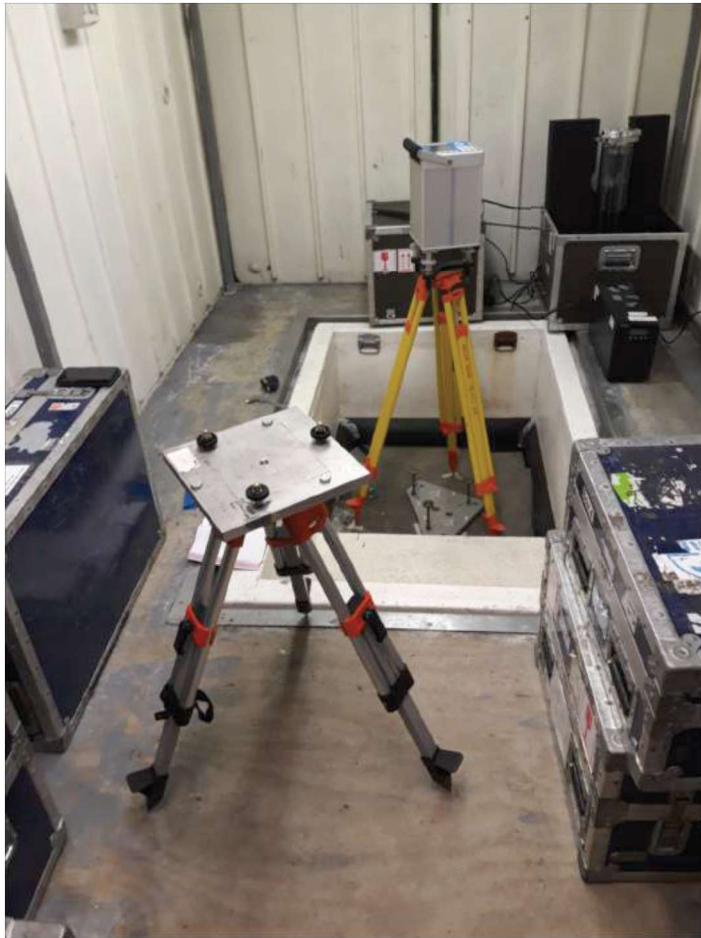
### Site photos

#### Scott Base SBG1



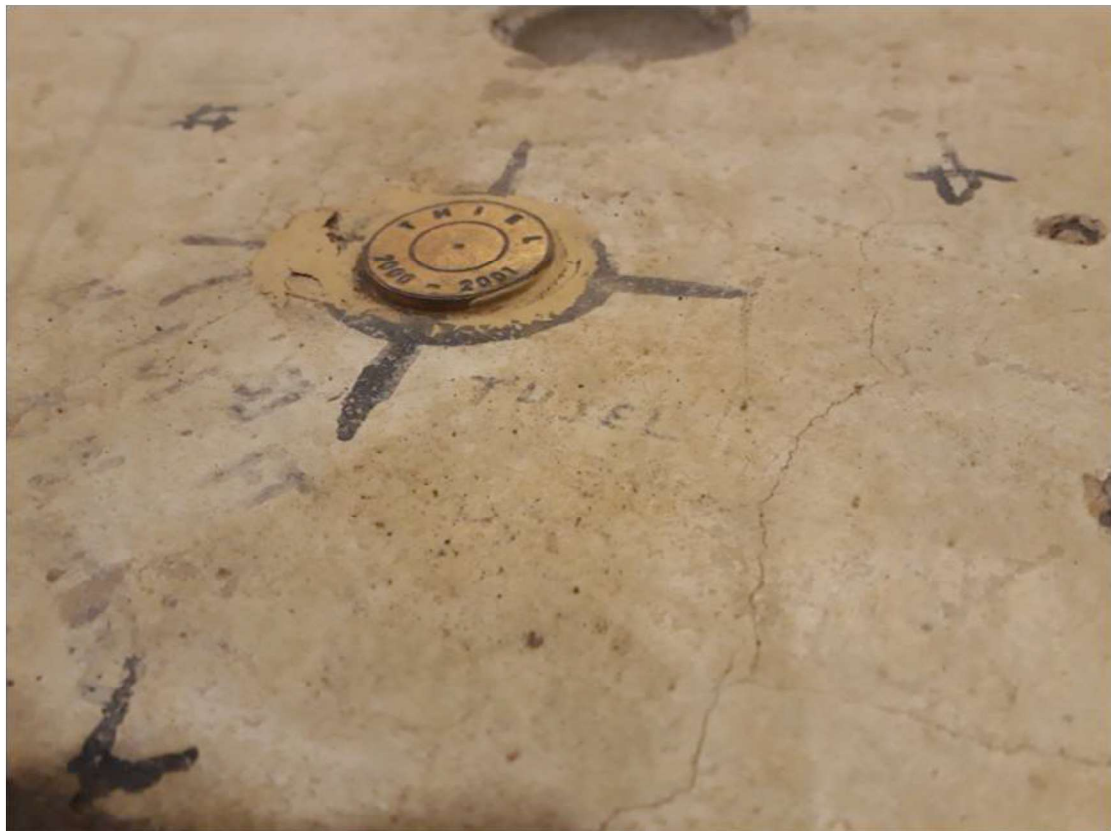
The measurements were done inside a container usually used as a shelter for divers. The opening in the floor of the container was almost a perfect match for the size of the pillar. The opening and the pillar were additionally insulated with rubber foam to keep wind from reaching the gravimeter.





McMurdo Thiel-1







## Crater Hill SBGR



The gravity point is below the dive hut seen between the leftmost and center wind turbine.



