Gravity survey at McMurdo Station, Scott Base, and Mario Zucchelli Station, Antarctica, 13 November-13 December 2011

Technical Report by

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Abstract

From 13 November until 13 December 2011, absolute gravity observations have been conducted at the USGS Thiel-1 gravity benchmark at McMurdo Station (US), LINZ SBG1 benchmark at Scott Base (NZ) and Terra Nova Bay AB and IAGS benchmarks at Mario Zucchelli Station (I) in Antarctica using the gravimeter FG5 #206. The Thiel-1 and SBG1 stations had been occupied in 2009, the Terra Nova Bay AB Station, in 1995, 1997 and 2009, and the Terra Nova Bay IAGS station, in 1990.

From 27 November until 10 December 2011, Thiel-2 benchmark at McMurdo Station and three benchmarks at Mount Fleming, among which FLM5, have been tied to Thiel-1 station, and the relative gravity station IRGS at Mario Zucchelli Station has been tied to Terra Nova Bay AB Station with a Scintrex CG-5 gravimeter.



McMurdo Station (MCM) and Scott Base (SB), which are 3 km apart, Mount Fleming (FLM5) and Mario Zucchelli Station (MZU).

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Introduction

1.1 Gravity survey in Antarctica

Originally, the goal of the gravity survey described in the present report was to make Absolute Gravity (AG) and Relative Gravity (RG) measurements at McMurdo Station (McM) and Scott Base (SB, Figure 1.1) on Ross Island, Mario Zucchelli Station (MZS) in Terra Nova Bay and Dumont d'Urville (DdU) in Terre Adélie, as well as RG measurements at Mount Fleming (MF) in the Dry Valleys. However, because of logistical difficulties, the observation at DdU was cancelled.

In the following chapters, we successively report on the observations made at McM, MF, SB and MZS. Where available, we compare the observations to measurements previously made at the same locations.

This paper is complementary to the report by Rogister et al. (2009), hereafter referred to as Report I, of the similar 2009 campaign. However, necessary information, such as geographical coordinates or environmental and instrumental parameters, is reproduced in the present report to make it self-contained.

Observations were also conducted by J. Emil Nielsen (JEN), from the Technical University of Denmark, with an A10 absolute gravimeter designed by Mirco-g Lacoste. They are presented in a separate report (Nielsen 2012).

A paper by Peter Rejcek on the Polar Earth Observing Network (POLENET) project has been published in March 2012 in the Antarctic Sun (http://antarcticsun.usap.gov/science/contentHandler.cfm?id=2615). It includes a description of the 2011 AG measurements.

1.2 Financial and logistical supports

Initiated as a part of project 337 Variation de gravité et mouvement vertical dans les régions polaires - Apport aux problèmes du rebond post-glaciaire et de la déglaciation actuelle funded by the French Institut Paul-Emile Victor (IPEV) and led by Jacques Hinderer (IPGS), the 2011 AG survey in Antarctica also benefited from the support of the Italian Programma Nazionale di Ricerche in Antartide (PNRA), Land Information New Zealand (LINZ), Antarctica New Zealand (ANZ), and US Antarctic Program (USAP) managed by the National Science Foundation (NSF). It is a part of the international POLENET.

1.3 Equipment

The AG observations were conducted with the free-fall FG5 #206 gravimeter designed by Micro-g Lacoste, owned by the French Institut National des Sciences de l'Univers (INSU), run by the IPGS and operated by Jean-Daniel Bernard who was assisted by Larry Hothem and Yves Rogister. Observations consisted of sets of 100 drops, one drop every 10 seconds, which were hourly or half-hourly repeated. The AG raw data are corrected for Earth tide, ocean loading, polar motion and atmospheric pressure. The corrections and instrumental parameters are given, for each station, in Appendix D.

The RG observations and gravity gradient measurements were made with a Scintrex CG-5 gravimeter owned and kindly lent to us by the INSU. The operators were JDB and YR.



Figure 1.1: Hut over SBG1 benchmark at Scott Base.

McMurdo Station (US)

2.1 AG at Thiel-1 Station

Thiel gravity station, whose geographical coordinates are given in Table 2.1, is established in Building 146 (Fig. 2.3) at McMurdo Station on Ross Island. Thiel-1 benchmark is on a concrete pier inside the building and Thiel-2 benchmark is on a concrete pier outside the building (Fig. 2.3). We only occupied Thiel-1 station with the FG5 gravimeter (Fig. 2.1) and linked Thiel-2 to Thiel-1 with the CG-5 Scintrex relative meter (Section 2.2).

This was the second AG measurement at Thiel station. The first one had taken place in November 2009 (Report I). The observations used to obtain the values given in Table 2.2 ran from 21 until 23 November 2011 (local time). Sets of 100 drops were repeated every 30 minutes. Other observation sessions were also recorded but the quality of the data is poorer than the ones shown in Fig. 2.2. The mean gravity values measured in 2009 and 2011 at the ground level and 1 m above ground are given in Table 2.2.

The vertical gravity gradient was measured on 5 December. Its value was -2.988 \pm 0.052 μ Gal/cm. However, to consistently compare the 2009 and 2011 AG measurements, the gradient measured in 2009 and given in Table 2.1 was used when processing the FG5 data.

2.2 Gravity link to Thiel-2

On 27 November 2011, the Thiel-2 benchmark was linked to Thiel-1 station (Fig. 2.3), providing the gravity value of Table 2.3.

Table 2.1: Geographical coordinates of and vertical gravity gradient at Thiel-1 station.

Station	Latitude (°)	Longitude (°)	Elevation (m)	dg/dz (μ Gal/cm)
Thiel-1	77.8490 S	166.6794 E	46.21	-3.114 ± 0.030



Figure 2.1: FG5 #206 installed over Thiel-1 benchmark. Scintrex CG-5 on the right on the pillar.

Table 2.2: AG at Thiel-1	Station at ground leve	1 and 1 m above ground.
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Year Reference Alt	itude above ground (m)	$g (\mu \text{Gal})$
2009 Report I	0	$982\ 970\ 532.28\pm 4.30$
2009 Report I	1	$982\ 970\ 220.88\pm 2.07$
2011 This report	0	$982\ 970\ 543.42\pm 4.39$
2011 This report	1	$982\ 970\ 232.02\pm 2.14$

Table 2.3: Gravity at Thiel-2 benchmark.

Station	Year	Δg wrt Thiel-1 (mGal)
Thiel-2	2011	317.8 ± 5.1



Figure 2.2: AG time series at ground level at Thiel-1 Station. Time is UT. The resulting AG value is given in Table 2.2.



Figure 2.3: *Top*: Scintrex CG-5 installed over Thiel-2 benchmark in front of Thiel station. *Bottom left*: Thiel-2 benchmak on the outside concrete pillar. *Bottom right*: Thiel-2 plate on the concrete foundation of Thiel station.

Mount Fleming

On 3 December, we have had the opportunity to tie a site of the GNSS network of the POLENET project located on MF in the Dry Valleys. The site, whose GPS code is FLM5, has been tied to Thiel-1 station by helicopter. A simultaneous absolute measurement has been made with an A10 absolute gravimeter (Nielsen 2012).



Figure 3.1: *Left*: Scintrex CG5 relative gravimeter and A10 absolute gravimeter installed side by side at the Mt. Fleming GNSS site of the POLENET project. The Scintrex CG5 is protected from the sun in the shade of the blue coat (*right*) and the A10 is installed in the green tent. The g value given in Table 3.1 is the value at the location of the benchmark under the tent.

Table 3.1: Geographical coordinates of and gravity at FLM5 station.

Station	Latitude (°)	Longitude (°)	Elevation (m)	g (µGal)
FLM5	77.5327 S	160.2714 E	1868	982 442 236 ±11

Scott Base (NZ)

During this campaign, we occupied the station SBG1 only. Its geographical coordinates are given in Table 4.1. This was the second AG measurement at SBG1 station. The first one had taken place in November 2009

Table 4.1: Geographical coordinates of and vertical gravity gradient at SBG1 Station

Station	Latitude (°)	Longitude (°)	Elevation (m)	dg/dz (μ Gal/cm)
SBG1	77.8489 S	166.7691 E	9.1	-3.491 ± 0.030

(Report I). A hut, shown in Figure 4.1, larger than the hut set up in 2009, has been installed for the duration of the observations. The good-quality data providing the AG value given in Table 4.2 were acquired on 2 and 3 December (local time). Sets of 100 drops were hourly repeated. Other observation sessions were also recorded but the quality of the data is poorer than the ones shown in Fig. 4.2. The mean gravity values measured in 2009 at the ground level and 1 m above ground are also given in Table 4.2.

Table 4.2: AG at SBG1 Station at ground level and 1 m above ground.

Year	Reference	Altitude above ground (m)	$g \ (\mu \text{Gal})$
2009	Report I	0	982 977 945.91 \pm 4.34
2009	Report I	1	982 977 596.81 \pm 2.15
2011	This report	0	$982\ 977\ 940.22\pm 4.32$
2011	This report	1	$982\ 977\ 591.12\pm 2.10$

The vertical gravity gradient was measured on 28 November. Its value was -3.435 \pm 0.043 μ Gal/cm, in agreement with the value obtained in 2009, given in Table 4.1 and used when processing the FG5 data.



Figure 4.1: Hut and FG5 # 206 installed over SBG1 benchmark.



Figure 4.2: AG time series at ground level at SBG1 Station. Time is UT. The resulting AG value is given in Table 4.2.

Mario Zucchelli Station (I)

We have conducted AG observations at both TNB AB and IAGS stations. Their geographical coordinates are given in Table 5.1. IAGS has then been reoccupied with an absolute gravimeter for the first time since 1990 (Cerutti et al. 1992). As in 2009, we have tied the IAGS station to TNB AB and the IRGS station to IAGS. Moreover, we have tied the second pillar of the IAGS hut to both TNB AB and IAGS, which is the first pillar in the IAGS hut.

Table 5.1: Geographical coordinates of and vertical gravity gradient at TNB AB and IAGS stations. Elevation and gravity gradient given by Sasagawa et al. (2004) for TNB AB and by Cerutti at al. (1992) for IAGS.

Station	Latitude (°)	Longitude (°)	Elevation (m)	dg/dz (μ Gal/cm)
TNB AB	74.6933 S	164.0997 E	30	$\textbf{-3.120}\pm0.030$
IAGS	74.6934 S	164.0998 E	54.3	-3.570 ± 0.050

5.1 TNB AB Station

This was the fourth AG measurement at TNB AB station (Fig. 5.1). Previous measurements had taken place in 1995 (Sasagawa 2004), 1997 (Mäkinen et al. 2007) and 2009 (Report I). The data providing the AG value given in Table 5.2 were recorded from 7 to 9 December 2011 (local time). Sets of 100 drops were hourly repeated (Fig. 5.2). Fig. 5.2 shows the 44 AG values at the ground level, with their error bars. A residual diurnal tidal signal is clearly visible. The mean gravity values measured in 1995, 1997 and 2009 at the ground level and 1 m above ground are also given in Table 5.2.

5.2 IAGS Station

The hut of the Italian Absolute Gravity Station (IAGS) contains two pillars (Fig. 5.3) but only one pillar has been occupied with absolute gravimeters. So was it for the first time in 1990 with an Italian IMGC absolute gravimeter. For reasons explained in Report I, it had not been reoccupied with an absolute meter since then. A tie to TNB AB has, however, been made in 2009 (Report I) and has again been made during the present campaign on 8 December (Table 5.3). We have run AG observations on this pillar from 10 until 12 December (local time). Sets of 100 drops were hourly repeated (Fig. 5.4).

The vertical gravity gradient has been measured on 8 December. Its value is $-3.737 \pm 0.022 \,\mu$ Gal/cm. However, to allow for a consistent comparison with the 1990 AG measurements, we have used the gradient estimated from data given by Cerutti et al. (1992) to process the present AG observations.



Figure 5.1: FG5 # 206 installed at TNB AB Station.

5.2.1 Gravity links to IAGS second pillar and IRGS station

We have tied the second pillar in the IAGS hut to TNB AB on 11 December and to the first pillar (IAGS) in the IAGS hut on 12 December. The IRGS station (Fig. 5.5) has been tied to TNB AB on 10 December. The gravity values are given in Table 5.4. The g values at the second pillar of the IAGS hut, obtained with two different ties, are in remarkably good agreement.

Table 5.2: AG measured with FG5 meters at TNB AB station at ground level and 1 m above ground. The 1995 value given by Sasagawa et al. (2004) has been corrected back by Mäkinen et al. (2007) for both Earth tides and instrumental factors. So, the same corrections have been applied to Sasagawa et al.'s data and our data, which allows for a comparison of the gravity values.

Year	Reference	Altitude above ground (m)	$g (\mu \text{Gal})$
1995	Mäkinen et al. 2007	1	982 865 664.1 \pm 2.1
1997	Mäkinen et al. 2007	1	982 865 663.4
2009	Report I	0	982 865 966.18 \pm 4.33
2009	Report I	1	982 865 654.18 \pm 2.09
2011	This report	0	982 865 970.21 \pm 4.37
2011	This report	1	982 865 658.21 \pm 2.12

Table 5.3: AG at IAGS station.

Year	Reference	Type of measurement	Altitude above ground (m)	$g \ (\mu \text{Gal})$
1990	Cerutti et al. (1992)	Direct (IMGC meter)	0	982 855 244 \pm 7
2009	Report I	Tie to TNB AB	0	982 855 317 \pm 12
2011	This report	Tie to TNB AB	0	982 855 317 \pm 12
2011	This report	Direct (FG5 meter)	0	982 855 316.84 \pm 4.39
2011	This report	Direct (FG5 meter)	1	$982\ 584\ 959.84 \pm 2.14$



Figure 5.2: AG time series at ground level at TNB AB station. Time is UT. The resulting AG value is given in Table 5.2.



Figure 5.3: *Left*: Italian AG Station (IAGS) at MZS, with Mt. Melbourne in the back. *Right* : The pillar near the entrance door, with a plate on it, is where AG observations have been made (see also Figs 5.4 and 5.5 in Report I).



Figure 5.4: AG time series at ground level at IAGS station. Time is UT. The resulting AG value is given in Table 5.3.

Year	Reference	Tied station	Reference station	$g \ (\mu \text{Gal})$
2011	This report	IAGS 2	TNB AB	$982\ 855\ 298\pm 6$
2011	This report	IAGS 2	IAGS	$982\ 855\ 298\pm 5$
1990	Cerutti et al. 1992	IRGS	IAGS	$982\ 863\ 890\pm 33$
1995	Sasagawa 2004	IRGS	TNB AB	$982\ 863\ 935 \pm 13$
2009	Report I	IRGS	TNB AB	$982\ 863\ 951 \pm 12$
2011	This report	IRGS	TNB AB	$982\ 863\ 947 \pm 6$

Table 5.4: Gravity ties to IAGS second pillar, named here IAGS 2, and IRGS station.



Figure 5.5: IRGS benchmark.

Conclusions

Despite the cancellation of the observation at DdU, the gravity survey described in this report has been very successful. AG measurements have been repeated at Thiel-1 station (McM), SBG1 station (SB), TNB AB and IAGS stations (MZS). Various stations have been tied with a relative gravimeter to the AG reference stations: Thiel-2 station (McM), IAGS and IRGS stations (MZS), and Mount Fleming station. The latter was simultaneously occupied with an A10 absolute gravimeter owned by DTU Space (Denmark) and operated by JEN.

Fig. 6.1 shows the AG values measured at McM, SB and MZS during the 2009 and 2011 campaigns, as well as values previously obtained at the same and other (DdU, Satgrav at McM) stations. The 2009 value at IAGS (Section 5.2) has been obtained from a tie to TNB AB, which explains the large error bar. In this plot, it is the only observation that has not been made with an absolute gravimeter.

The large gravity increase of 73 μ Gal at IAGS between 1990 and 2009 is intriguing. It is in contradiction with the small gravity decrease of 10 μ Gal observed at TNB AB between 1995 and 2009. The validity of the 2009 measurements has, however, been confirmed in 2011. A part, difficult to assess precisely, of the difference between the 1990 and 2009 values at IAGS could be explained by the use of the rise-and-fall IMGC instrument in 1990. Indeed, at the third international comparison of (9) absolute gravimeters organized in Sèvres, France, in 1989, it provided the smallest gravity value, some 23 μ Gal smaller than the biggest value given by the GABL intrument from USSR (Boulanger et al. 1991, Marson et al. 1995). The fourth international comparison of (11) absolute gravimeters organized at the same place in 1994 saw the first participation of 5 FG5 meters (Marson et al. 1995). The IMGC instrument then provided a value that was, at most, 6 μ Gal smaller than the FG5 and JILAg setup in the exact same place.

Table 6.1: Reference gravity values g_0 (in μ Gal = 10⁻⁸ m/s²) for Fig. 6.1.

MZS (TNB AB)	982 865 600
MZS (IAGS)	982 855 230
McM (Satgrav)	982 972 700
McM (Thiel-1)	982 970 200
SB	982 977 550
DdU	982 387 100



Figure 6.1: Difference (in μ Gal = 10⁻⁸ m/s²) between the actual gravity and g_0 given in Table 6.1 at the four stations occupied during the 2009 and 2011 campaigns (Thiel 1, SB, TNB AB and IAGS). Gravity values at the former AG station at McM (Satgrav) and DdU station are also plotted.

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Appendix A

List of Acronyms

AG	Absolute Gravity
ANZ	Antarctica New Zealand
DdU	Dumont d'Urville
IAGS	Italian AG Station
INSU	Institut National des Sciences de l'Univers
IPEV	Institut Paul-Emile Victor
IPGS	Insitut de Physique du Globe de Strasbourg
IRGS	Italian RG Station
JDB	Jean-Daniel Bernard
JEN	J. Emil Nielsen
LH	Larry Hothem
LINZ	Land Information New Zealand
McM	McMurdo Station
MF	Mount Fleming
MZS or MZU	Mario Zucchelli Station
NSF	National Science Foundation
PNRA	Programma Nazionale di Ricerche in Antartide
POLENET	Polar Earth Observing Network
RG	Relative Gravity
SB	Scott Base
TNB	Terra Nova Bay
USAP	US Antarctic Program
USGS	US Geological Survey
YR	Yves Rogister

Appendix B

Web sites

ANZ	http://www.antarcticanz.govt.nz/
INSU	http://www.insu.cnrs.fr/
IPEV	http://www.institut-polaire.fr/
IPGS	http://eost.unistra.fr/recherche/ipgs/
LINZ	http://www.linz.govt.nz/
PNRA	http://www.pnra.it/
POLENET	http://www.polenet.org/
USAP	http://www.usap.gov/
USGS	http://www.usgs.gov/

Appendix C

Event Log

Local time is UT + 13. Because of this time difference, dates may be different from the dates in the text.

- 9 Nov JDB, LH and YR arrive in McM
- 10 Nov Equipment delivered at the Crary Lab. Start vacuum pomp. Borrow a 110 V UPS
- 11 Nov JDB attends mandatory survival school
- 12 Nov JEN arrives in McM
- 13 Nov FG5 setup at Thiel station. Start AG mesaurements
- 17 Nov PM Move FG5 to SB
- 18 Nov Start AG measurements at SBG1
- 20 Nov Stop AG measurements at SBG1. Move FG5 to Thiel station. Start AG measurements at Thiel
- 28 Nov Gravity link to Thiel-2 with Scintrex CG-5
- 29 Nov AM Vertical gradient at SBG1. PM Move FG5 to SBG1
- 03 Dec Gravity link to MF in the Dry Valleys with Scintrex CG-5.
- 05 Dec Vertical gradient at Thiel station
- 07 Dec JDB, LH and YR fly to MZS. Arrive at 5 pm. FG5 setup at TNB AB
- 08 Dec Start AG measurements at TNB AB
- 09 Dec Vertical gradient at IAGS
- 09 Dec Move FG5 to IAGS. Start AG measurements
- 11 Dec Gravity link from TNB AB to IRGS with Scintrex CG-5
- 12 Dec Gravity link from TNB AB to second pillar in IAGS hut with Scintrex CG-5
- 13 Dec AM Dismount FG5. PM Gravity tie between the two pillars in IAGS hut with Scintrex CG-5. JEN flies to ChC, NZ.
- 14 Dec Flight back to McM
- 16 Dec JDB and YR fly to ChC, NZ

Appendix D

Set processing log for AG measurements

Ground values are in red, 1-meter above ground values are in blue.

D.1 McMurdo Station

```
Micro-g Solutions g Processing Report
g Acquisition Version: 8.090227
g Processing Version: 7.070307
Station Data
Name: McMurdo
Site Code: Thiel-1
Lat: -77.84900 Long: 166.67940 Elev: 46.21 m
Setup Height: 15.30 cm
Transfer Height: 0.00 cm
Transfer Height: 100.00 cm
Actual Height: 131.50 cm
Gradient: -3.114 \ \mu \text{Gal/cm}
Nominal Air Pressure: 1007.71 mBar
Barometric Admittance Factor: 0.30
Polar Motion Coord: 0.1744 " 0.2987 "
Earth Tide (ETGTAB) Selected
Potential Filename: ETCPOT.dat
Delta Factor Filename: OceanLoad-Thiel-1-Thiel-1.dff
Delta Factors
Start Stop Amplitude Phase Term
0.000000 0.002427 1.000000 0.0000 DC
0.002428 0.249951 1.160000 0.0000 Long
0.721500 0.906315 1.154250 0.0000 Q1
0.921941 0.974188 1.154240 0.0000 01
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: OceanLoad-Thiel-1-Thiel-1.olf Waves: M2 S2 K1 O1 N2 P1 K2 Q1 Mf Mm Ssa Amplitude (μ Gal): 0.673 0.258 1.845 1.488 0.094 0.621 0.069 0.347 0.278 0.219 0.203 Phase (deq): -329.0 -119.3 -157.0 -145.7 -11.6 -158.9 -149.3 -141.9 -20.6 -11.2 -16.5 Instrument Data Meter Type: FG5 Meter S/N: 206 Factory Height: 116.20 cm Rubidium Frequency: 1000000.00000 Hz Laser: WEO100 (146) ID: 632.99117754 nm (0.21 V) IE: 632.99119473 nm (-0.25 V) IF: 632.99121259 nm (-0.56 V) IG: 632.99123023 nm (-0.58 V) IH: 632.99136890 nm (-0.80 V) II: 632.99139822 nm (-0.67 V) IJ: 632.99142704 nm (-0.53 V) Modulation Frequency: 8333.383 Hz Processing Results Date: 11/22/11 Time: 04:29:07 DOY: 326 Year: 2011 Time Offset (D h:m:s): 0 0:0:0 Gravity: 982970543.42 µGal Gravity: 982970229.77 µGal Set Scatter: 3.97 μ Gal Measurement Precision: 0.44 μ Gal Total Uncertainty: 4.39 µGal Total Uncertainty: 2.14 μ Gal Number of Sets Collected: 102 Number of Sets Processed: 84 Set #s Processed: 9,10,11,12,14,15,17,18,19,20,21,22,23,24,25,26,29,30,31,32,33,34,35,36, 37,38,39,40, 41,42,43,44,45,46,47,48,49,50,51,52,54,55,56,57,58,59, 60,61,62,63,64,65,66,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84, 85,86,87,88,89,90,91,92,93,94,95,96,97,98,100 Number of Sets NOT Processed: 18 Set #s NOT Processed: 1,2,3,4,5,6,7,8,13,16,27,28,53,67,68,99,101,102 Number of Drops/Set: 100 Total Drops Accepted: 7058 Total Drops Rejected: 1342 Total Fringes Acquired: 700 Fringe Start: 30

```
Processed Fringes: 641
GuideCard Multiplex: 4
GuideCard Scale Factor: 250
Acquisition Settings
Set Interval: 30 min
Drop Interval: 10 sec
Number of Drops: 100
Gravity Corrections
Earth Tide (ETGTAB): -70.59 \muGal
Ocean Load: 0.73 \muGal
Polar Motion: -1.88 \muGal
Barometric Pressure: -8.97 \muGal
Transfer Height: 409.49 \muGal
Transfer Height: 98.09 Gal
Reference Xo: -0.00 \ \muGal
Uncertainties
Sigma Reject: 2.00
Earth Tide Factor: 0.001
Average Earth Tide Uncertainty: 0.07 \muGal
Ocean Load Factor: 0.10
Average Ocean Load Uncertainty: 0.07 \muGal
Barometric: 1.00 \muGal
Polar Motion: 0.05 \muGal
Laser: 0.05 \muGal
Clock: 0.50 \muGal
System Type: 1.10 \muGal
Tidal Swell: 0.00 \muGal
Water Table: 0.00 \muGal
Unmodeled: 0.00 \muGal
System Setup: 1.00 \muGal
Gradient: 3.94 \muGal (0.03 \muGal/cm)
Gradient: 0.94 \muGal (0.03 \muGal/cm)
```

D.2 Scott Base

```
g Acquisition Version: 8.090227
g Processing Version: 7.070307
Station Data
Name: Scott Base
Site Code: SBG1
Lat: -77.84890 Long: 166.76910 Elev: 9.10 m
Setup Height: 13.05 cm
Transfer Height: 0.00 cm
Transfer Height: 100.00 cm
Actual Height: 129.25 cm
Gradient: -3.491 \ \mu \text{Gal/cm}
Nominal Air Pressure: 1012.16 mBar
Barometric Admittance Factor: 0.30
Polar Motion Coord: 0.1605 " 0.2841 "
Earth Tide (ETGTAB) Selected
Potential Filename: ETCPOT.dat
Delta Factor Filename: OceanLoad-SBG1.dff
Delta Factors
Start Stop Amplitude Phase Term
0.000000 0.002427 1.000000 0.0000 DC
0.002428 0.249951 1.160000 0.0000 Long
0.721500 0.906315 1.154250 0.0000 Q1
0.921941 0.974188 1.154240 0.0000 01
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: OceanLoad-SBG1.olf
Waves: M2 S2 K1 O1 N2 P1 K2 Q1 Mf Mm Ssa
Amplitude (\muGal):
0.674 0.259 1.852 1.493 0.094 0.624 0.069 0.348 0.278 0.220 0.204
Phase (deq):
-329.2 -119.6 -157.1 -145.7 -12.1 -158.9 -149.5 -141.9 -20.6 -11.2 -16.5
Instrument Data
Meter Type: FG5
Meter S/N: 206 Factory Height: 116.20 cm
Rubidium Frequency: 1000000.00000 Hz
Laser: WEO100 (146)
ID: 632.99117754 nm ( 0.20 V)
IE: 632.99119473 nm ( -0.21 V)
IF: 632.99121259 nm (-0.50 V)
IG: 632.99123023 nm ( -0.54 V)
```

```
IH: 632.99136890 nm ( -0.75 V)
II: 632.99139822 nm ( -0.62 V)
IJ: 632.99142704 nm (-0.49 V)
Modulation Frequency: 8333.383 Hz
Processing Results
Date: 12/02/11
Time: 18:51:14
DOY: 336
Year: 2011
Time Offset (D h:m:s): 0 0:0:0
Gravity: 982977940.22 µGal
Gravity: 982977591.12µGal
Set Scatter: 1.86 µGal
Measurement Precision: 0.36 \muGal
Total Uncertainty: 4.32 \muGal
Total Uncertainty: 2.09 \muGal
Number of Sets Collected: 41
Number of Sets Processed: 26
Set #s Processed: 2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,20,21,22,23,
24,25,26,27,28
Number of Sets NOT Processed: 15
Set #s NOT Processed: 1,19,29,30,31,32,33,34,35,36,37,38,39,40,41
Number of Drops/Set: 100
Total Drops Accepted: 2562
Total Drops Rejected: 38
Total Fringes Acquired: 700
Fringe Start: 30
Processed Fringes: 641
GuideCard Multiplex: 4
GuideCard Scale Factor: 250
Acquisition Settings
Set Interval: 60 min
Drop Interval: 10 sec
Number of Drops: 100
Gravity Corrections
Earth Tide (ETGTAB): -60.43 \muGal
Ocean Load: 0.09 \muGal
Polar Motion: -1.74 \muGal
Barometric Pressure: -12.57 \muGal
Transfer Height: 451.21 \muGal
Transfer Height: 102.11 \muGal
Reference Xo: -0.00 \muGal
Uncertainties
Sigma Reject: 3.00
Earth Tide Factor: 0.001
Average Earth Tide Uncertainty: 0.06 \muGal
```

Ocean Load Factor: 0.10 Average Ocean Load Uncertainty: 0.01 μ Gal Barometric: 1.00 μ Gal Polar Motion: 0.05 μ Gal Laser: 0.05 μ Gal Clock: 0.50 μ Gal System Type: 1.10 μ Gal Tidal Swell: 0.00 μ Gal Water Table: 0.00 μ Gal Unmodeled: 0.00 μ Gal System Setup: 1.00 μ Gal Gradient: 3.88 μ Gal (0.03 μ Gal/cm) Gradient: 0.88 μ Gal (0.03 μ Gal/cm)

D.3 Mario Zucchelli Station

D.3.1 TNB AB

Micro-g Solutions g Processing Report g Acquisition Version: 8.090227 g Processing Version: 7.070307 Station Data Name: Mario Zucchelli Station TNB AB Site Code: TNB AB Lat: -74.69477 Long: 164.11478 Elev: 30.00 m Setup Height: 14.70 cm Transfer Height: 0.00 cm Transfer Height: 100.00 cm Actual Height: 130.90 cm Gradient: $-3.120 \ \mu \text{Gal/cm}$ Nominal Air Pressure: 1009.65 mBar Barometric Admittance Factor: 0.30 Polar Motion Coord: 0.1577 " 0.2806 " Earth Tide (ETGTAB) Selected Potential Filename: OceanLoad-TNB AB.dff Delta Factors Start Stop Amplitude Phase Term 0.000000 0.002427 1.000000 0.0000 DC 0.002428 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: OceanLoad-TNB AB.olf Waves: M2 S2 K1 O1 N2 P1 K2 Q1 Mf Mm Ssa Amplitude (μ Gal): 0.672 0.304 2.109 1.760 0.057 0.709 0.092 0.423 0.301 0.246 0.224 Phase (deg): -304.9 -139.0 -161.5 -150.8 -44.0 -162.9 -165.5 -145.5 -20.1 -11.4 -14.8 Instrument Data Meter Type: FG5 Meter S/N: 206 Factory Height: 116.20 cm Rubidium Frequency: 1000000.00000 Hz Laser: WEO100 (146)

```
ID: 632.99117754 nm ( 0.20 V)
IE: 632.99119473 nm (-0.15 V)
IF: 632.99121259 nm ( -0.60 V)
IG: 632.99123023 nm ( -0.64 V)
IH: 632.99136890 nm ( -0.72 V)
II: 632.99139822 nm (-0.61 V)
IJ: 632.99142704 nm ( -0.50 V)
Modulation Frequency: 8333.383 Hz
Processing Results
Date: 12/08/11
Time: 21:21:44
DOY: 342
Year: 2011
Time Offset (D h:m:s): 0 0:0:0
Gravity: 982865970.21 µGal
Gravity: 982865658.21µGal
Set Scatter: 2.20 \muGal
Measurement Precision: 0.33 \muGal
Total Uncertainty: 4.37 \muGal
Total Uncertainty: 2.12 \muGal
Number of Sets Collected: 44
Number of Sets Processed: 44
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
Number of Sets NOT Processed: 0
Set #s NOT Processed:
Number of Drops/Set: 100
Total Drops Accepted: 4385
Total Drops Rejected: 15
Total Fringes Acquired: 700
Fringe Start: 30
Processed Fringes: 641
GuideCard Multiplex: 4
GuideCard Scale Factor: 250
Acquisition Settings
Set Interval: 60 min
Drop Interval: 10 sec
Number of Sets: 44
Number of Drops: 100
Gravity Corrections
Earth Tide (ETGTAB): -38.91 \muGal
Ocean Load: -0.38 \muGal
Polar Motion: -2.23 \muGal
Barometric Pressure: -10.42 \muGal
Transfer Height: 408.41 \muGal
Transfer Height: 96.41 Gal
Reference Xo: -0.00 \ \mu Gal
```

```
Uncertainties
Sigma Reject: 3.00
Earth Tide Factor: 0.001
Average Earth Tide Uncertainty: 0.04 \muGal
Ocean Load Factor: 0.10
Average Ocean Load Uncertainty: 0.04 \muGal
Barometric: 1.00 \muGal
Polar Motion: 0.05 \muGal
Laser: 0.05 \muGal
Clock: 0.50 \muGal
System Type: 1.10 \muGal
Tidal Swell: 0.00 \muGal
Water Table: 0.00 \muGal
Unmodeled: 0.00 \muGal
System Setup: 1.00 \muGal
Gradient: 3.93 \muGal (0.03 \muGal/cm)
Gradient: 0.93 \muGal (0.03 \muGal/cm)
```

D.3.2 IAGS

Micro-g Solutions g Processing Report g Acquisition Version: 8.090227 g Processing Version: 7.070307 Station Data Name: Mario Zucchelli Station IAGS Site Code: IAGS Lat: -74.69340 Long: 164.09980 Elev: 54.30 m Setup Height: 15.20 cm Transfer Height: 0.00 cm Transfer Height: 100.00 cm Actual Height: 131.40 cm Gradient: $-3.570 \ \mu \text{Gal/cm}$ Nominal Air Pressure: 1006.74 mBar Barometric Admittance Factor: 0.30 Polar Motion Coord: 0.1539 " 0.2783 " Earth Tide (ETGTAB) Selected Potential Filename: ETCPOT.dat Delta Factor Filename: OceanLoad-IAGS.dff Delta Factors Start Stop Amplitude Phase Term 0.000000 0.002427 1.000000 0.0000 DC 0.002428 0.249951 1.160000 0.0000 Long 0.721500 0.906315 1.154250 0.0000 Q1 0.921941 0.974188 1.154240 0.0000 01 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: OceanLoad-IAGS.olf Waves: M2 S2 K1 O1 N2 P1 K2 Q1 Mf Mm Ssa Amplitude (μ Gal): 0.672 0.304 2.108 1.760 0.057 0.709 0.092 0.423 0.301 0.246 0.224 Phase (deq): -304.9 -139.0 -161.5 -150.8 -44.0 -162.9 -165.5 -145.5 -20.1 -11.4 -14.8 Instrument Data Meter Type: FG5 Meter S/N: 206 Factory Height: 116.20 cm Rubidium Frequency: 1000000.00000 Hz Laser: WE0100 (146) ID: 632.99117754 nm (0.20 V) IE: 632.99119473 nm (-0.15 V) IF: 632.99121259 nm (-0.47 V) IG: 632.99123023 nm (-0.48 V) IH: 632.99136890 nm (-0.69 V) II: 632.99139822 nm (-0.60 V) IJ: 632.99142704 nm (-0.50 V) Modulation Frequency: 8333.383 Hz Processing Results Date: 12/11/11 Time: 12:16:10 DOY: 345 Year: 2011 Time Offset (D h:m:s): 0 0:0:0 Gravity: 982855316.84µGal Gravity: 982854959.84 µGal Set Scatter: 2.87 μ Gal Measurement Precision: 0.36 μ Gal Total Uncertainty: 4.39 μ Gal Total Uncertainty: 2.14 μ Gal Number of Sets Collected: 63 Number of Sets Processed: 63 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, 45,46,47,48,49,50,51,52,53,54, 55,56,57,58,59,60,61,62,63 Number of Sets NOT Processed: 0 Set #s NOT Processed: Number of Drops/Set: 100 Total Drops Accepted: 6260 Total Drops Rejected: 40 Total Fringes Acquired: 700

```
Fringe Start: 30
Processed Fringes: 641
GuideCard Multiplex: 4
GuideCard Scale Factor: 250
Acquisition Settings
Set Interval: 60 min
Drop Interval: 10 sec
Number of Drops: 100
Gravity Corrections
Earth Tide (ETGTAB): -41.60 \muGal
Ocean Load: -1.00 \muGal
Polar Motion: -2.19 \muGal
Barometric Pressure: -10.41 \muGal
Transfer Height: 469.10 \muGal
Transfer Height: 112.10 \muGal
Reference Xo: -0.00 \ \muGal
Uncertainties
Sigma Reject: 3.00
Earth Tide Factor: 0.001
Average Earth Tide Uncertainty: 0.04 \muGal
Ocean Load Factor: 0.10
Average Ocean Load Uncertainty: 0.10 \muGal
Barometric: 1.00 \muGal
Polar Motion: 0.05 \muGal
Laser: 0.05 \muGal
Clock: 0.50 \muGal
System Type: 1.10 \muGal
Tidal Swell: 0.00 \muGal
Water Table: 0.00 \muGal
Unmodeled: 0.00 \muGal
System Setup: 1.00 \muGal
Gradient: 3.94 \muGal (0.03 \muGal/cm)
Gradient: 0.94 \muGal (0.03 \muGal/cm)
```