Field Guide to Antarctic Gravity Stations Visited During the 2004-2005 AGASEA Airborne Campaign

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(Photo by Matthew Fields-Johnson)

TABLE OF CONTENTS

1. Field Guide to Major McMurdo Gravity Station Locations

Bldg 146: Gravity Benchmark Shack, USGS brass plaque labeled "THIEL"

The USGS THIEL gravity benchmark (Figure 1.1) was located in the Thiel Science Building until 2001- when the building was demolished to make way for the Crary Lab). At that time, the benchmark was moved to Bldg 146, a shack up the hill from Science Cargo but set back on the right side (Figure 1.2). The shack was originally used as a water pump house but was converted to a small, heated office with the installation of the benchmark. A description of the location (and the gravity reading there) is as follows from a compilation posted (as of Feb. 2005) on the wall inside Bldg. 146 (see Figure 1.8 for photograph of whole compilation) (J. Bucher, unpublished data, 2003):

> "Pier inside old Water Transfer Pump House Building
> USGS Brass Disk "Thiel Gravity Base Station" 2001-2002
> Lat: -77˚ 50' 55.9068'' / -77.8490˚
> Long: 166˚ 40' 45.9629'' / 166.6794˚
> Elev: 46.21 m above MSL
> Absolute Gravity (mGals): 982970.52"

As of 2007, no absolute gravity readings had been done in Bldg. 146 and Thiel had only been tied to absolute gravity by hand or by upward continuation of an old value to its current location. There are plans to demolish this marker in the 2007-2008 season and establish a new gravity benchmark elsewhere in McMurdo.

Figure 1.1: THIEL Gravity Benchmark in Bldg 146

Figure 1.2: The Gravity Shack (Building 146), uphill from Science Cargo and the BFC.

Hut Point: USGS brass plaque labeled BC-4

There are two USGS satellite triangulation benchmarks on Hut Point but only one has a record of gravity measurements associated with it. The benchmark on top of the concrete pillar (visible in Figure 1.3 and featured in Figure 1.4) is named “Astro Pier” and there are no gravity measurements associated with this benchmark. The second benchmark is mounted on a weather-beaten concrete block in the ground a few meters from the “Astro Pier” and the brass plaque reads “BC-4” (Figure 1.5). A description of the location and the gravity reading there is as follows (J. Bucher, unpublished data, 2003):

> “International Satellite Triangulation Station
> Brass Disk “Station Number 053 B-04” 1969
> Lat: -77˚ 50’ 41.1720’’ / -77.8448˚
> Long: 166˚ 38’ 30.6278’’ / 166.6418˚
> Elev: 17.58 m above sea level
> NIMA Station ID: 0-185-6
> Absolute Gravity (mGals): 982976.62”

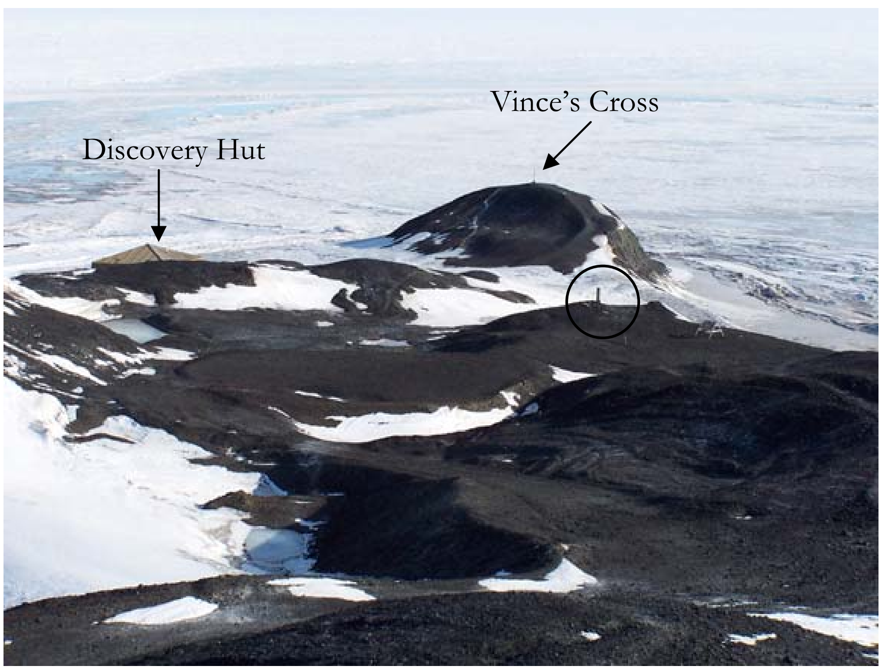


Figure 1.3: Location of USGS benchmarks (black circle) on Hut Point, McMurdo.

Figure 1.4: Satellite Triangulation Marker “Astro Pier”

Figure 1.5: Satellite Triangulation and Gravity Marker labeled “BC-4”

Bldg 139(Abandoned FSTOP office in 2005)- SEISMIC plaque

A metal pin (Figure 1.6) is located in a concrete pad at this location but lacks any other distinguishing markers. Based on description of the site (Figure 1.7) that follows (J. Bucher, unpublished data, 2003), this is the assumed location of the SEISMIC plaque:

> "SE corner of building on concrete pad
> USGS Brass Disk "SEISMIC" 1966-67
> Lat: -77 deg 50' 55.15'' / -77.8487 deg
> Long: 166 deg 40' 47.93'' / 166.6800 deg
> Elev: 49.29 m above MSL
> NIMA Station ID: 0-185-4
> Absolute Gravity (mGals): 982970.18"

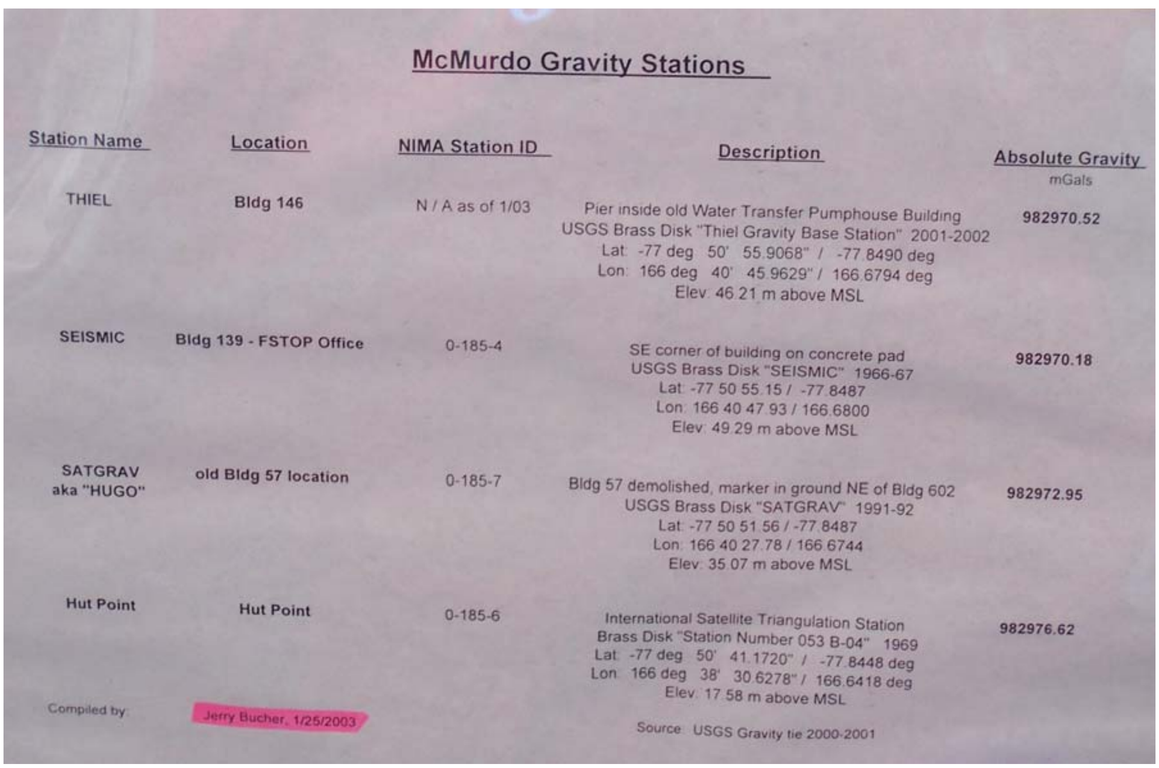
Figure 1.6: Metal pin in concrete slab on ground- assumed location of SEISMIC

Figure 1.7: SE corner of Bldg. 139

SATGRAV aka. HUGO marker near old Building 57

This marker was moved from Building 57 (old MEC) to the ground northeast of Bldg 602 when Bldg 57 was demolished to make way for Building 4 (SSC). Building 602 was subsequently also demolished in 2003 to make room for an extension to Building 4 and the marker was also demolished in 2003. A description of the location is as follows (J. Bucher, unpublished data, 2003):

> "Building 57 demolished, marker in ground NE of Bldg 602
> USGS Brass Disk "SATGRAV" 1991-1992
> Lat: -77 deg 50' 51.66'' / -77.8487 deg
> Long: 166 deg 40' 27.78'' / 166.6744
> Elev: 35.07 m above MSL
> NIMA Station ID: 0-185-7
> Absolute Gravity (mGal): 982972.95"



McMurdo Gravity Stations

Station Name	Location	NIMA Station ID	Description	Absolute Gravity mGals
THIEL	Bldg 146	N / A as of 1/03	Pier inside old Water Transfer Pumphouse Building USGS Brass Disk "Thiel Gravity Base Station" 2001-2002 Lat: -77 deg 50' 55.9068" / -77.8490 deg Lon: 166 deg 40' 45.9629" / 166.6794 deg Elev: 46.21 m above MSL	982970.52
SEISMIC	Bldg 139 - FSTOP Office	0-185-4	SE corner of building on concrete pad USGS Brass Disk "SEISMIC" 1966-67 Lat: -77 50 55.15 / -77.8487 Lon: 166 40 47.93 / 166.6800 Elev: 49.29 m above MSL	982970.18
SATGRAV aka "HUGO"	old Bldg 57 location	0-185-7	Bldg 57 demolished, marker in ground NE of Bldg 602 USGS Brass Disk "SATGRAV" 1991-92 Lat: -77 50 51.56 / -77.8487 Lon: 166 40 27.78 / 166.6744 Elev: 35.07 m above MSL	982972.95
Hut Point	Hut Point	0-185-6	International Satellite Triangulation Station Brass Disk "Station Number 053 B-04" 1969 Lat: -77 deg 50' 41.1720" / -77.8448 deg Lon: 166 deg 38' 30.6278" / 166.6418 deg Elev: 17.58 m above MSL	982976.62

Compiled by: Jerry Bucher, 1/25/2003

Source: USGS Gravity tie 2000-2001

Figure 1.8: The "McMurdo Gravity Stations" compilation done by J. Bucher (unpublished data, 2003), hanging in Bldg. 146 in 2004-2005.

2. Field Guide to South Pole Gravity Station Locations

Old South Pole Marker: In dome, metal pier in ice

The Old South Pole marker was established by researchers from the University of Wisconsin, Madison (possibly in 1989?). It is a cylindrical metal pier embedded in the ice beneath the Dome (Figure 2.1) and accessed through a hatch in the floor of one of the storage buildings (being used for computer parts storage in 2004). The location was marked with a paper on the ceiling indicating the gravity station and we had to unroll a floor mat to reveal the hatch (Figure 2.2). Two sheets of field notebook paper stapled to the floor beneath the hatch reveal the following visitors and readings:

Neal Lord (UW Madison) 1/21/89 to 1/26/89		
1/26/89	G1	5808.76
	G19	5703.92
T. Clarke		
1/22/92	G1	5812.49
	G19	5790.32
Peter Buckholder & Chen Liu		
1/25/94	G1	5813.72
(~1300 hrs)	G19	5779.41
Carol Finn (USGS) & Vicki Langenheim (USC)		
	G161	5743.36
	C191	5772.65
Marcy Davis & Vicki Langenheim (SOAR)		
12/18/98 08:54	G-64	5717.43

We added Theresa Diehl and Irina Filina to the list in 2004 (see values in Table 4.2).

However, this marker was decommissioned during the demolition of the old station, which started in the winter after the 2004-2005 season (P. Sullivan, pers. comm., 2008).

Figure 2.1: Metal pier gravity station below floor hatch in the South Pole Dome

Figure 2.2: Metal pier gravity station with handheld gravimeter for scale.

New South Pole Marker: Recessed wooden in snow tunnels

The new gravity station at South Pole (Figure 2.3) is located at the end of one of the snow utility tunnels at the pole (Figures 2.4 and 2.5, labeled "Gravity vault"). The tunnel is accessed through a door and the vault is down a long, narrow passageway that is wide enough for only one person abreast because of utility pipes running through the tunnel. The station is clearly marked with a hanging sign (Figure 2.3), but is in a dark corner. I recommend bringing a flashlight or other light source in addition to the built-in lights on the gravimeter in order to easily see the readings. This station is awkward to access (Figure 3.6 and 3.7) since it is recessed into the snow of the tunnel floor. Layers of thick clothing and -50°F temperatures in the snow tunnel make kneeling/laying in the snow for any amount of time an uncomfortable experience. However, this new station is exceptionally quiet and yields very accurate readings.

Figure 2.3: New South Pole gravity station in the snow tunnels; the Science Support Supervisor in 2004, Paul Sullivan, showed us the location.

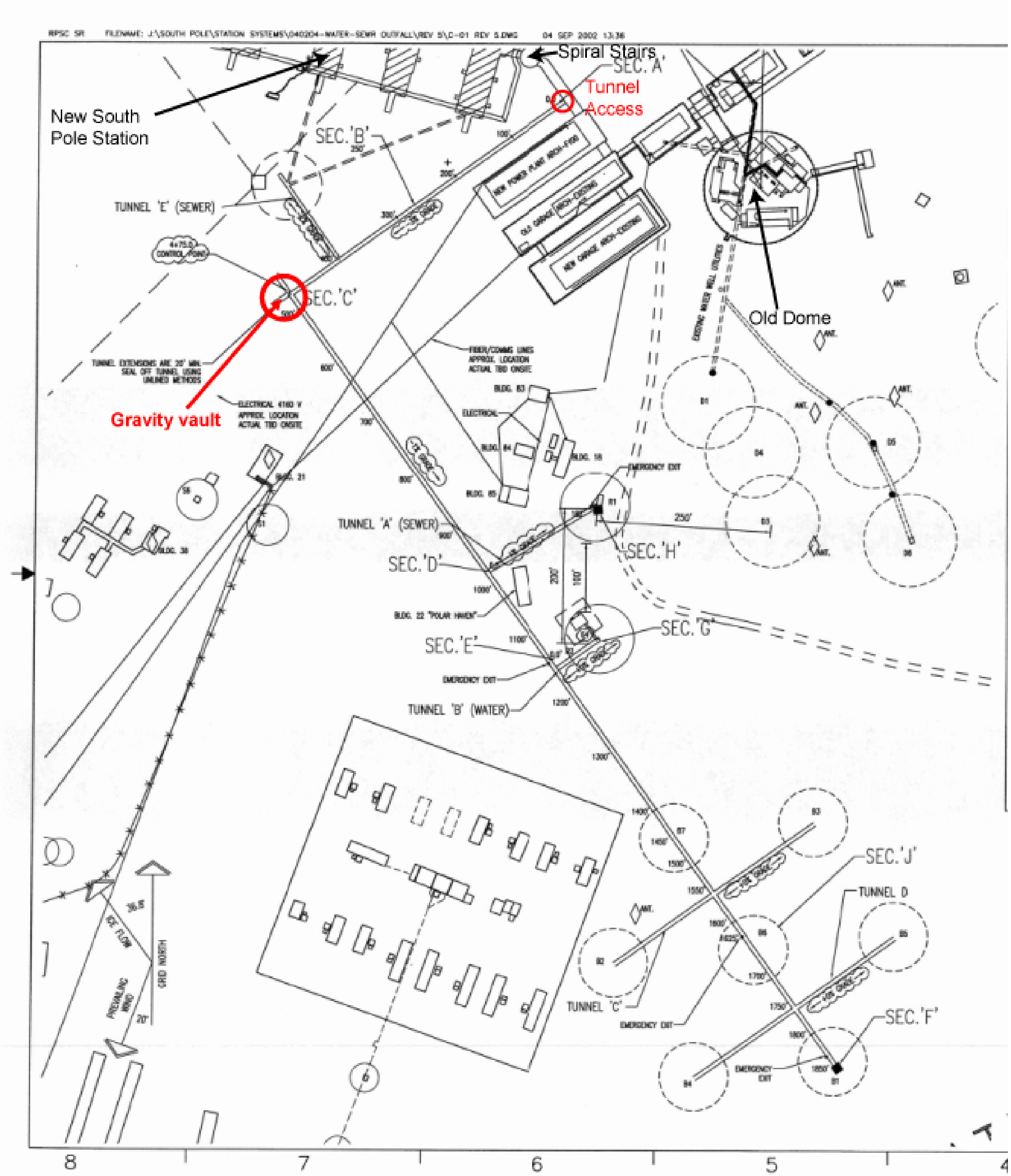


Figure 2.4: Raytheon Polar Services Sewer/Water Tunnel Plan at South Pole, sheet 2 of 25, drawn by C. Rock on 09/15/98. Labels added for the current location of the new gravity vault, old dome, new station, and spiral stairs (modified, image courtesy of P. Sullivan, pers. comm., 2008).

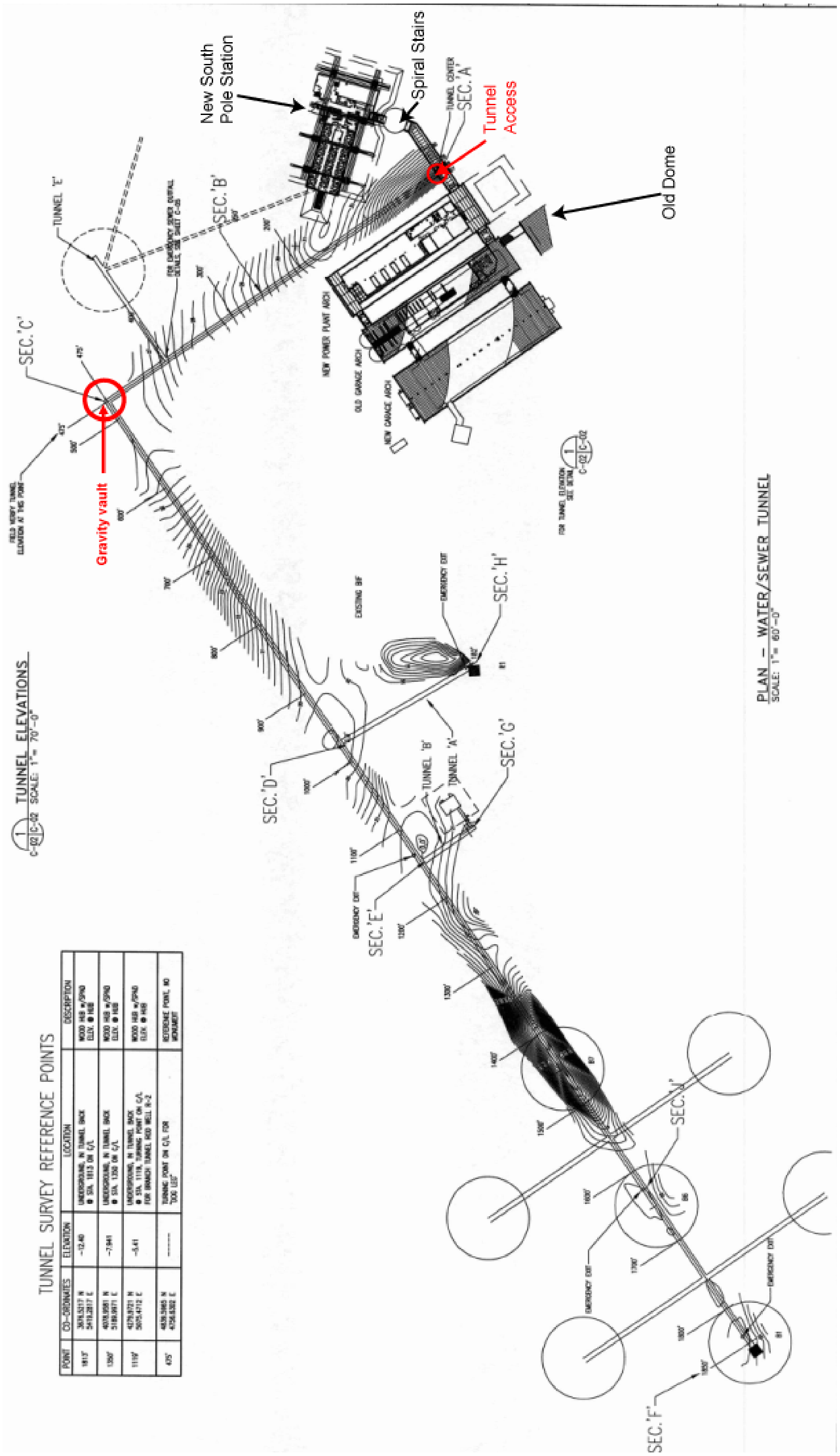


Figure 2.5: Raytheon Polar Services Sewer/Water Tunnel Profiles and Elevations at South Pole, sheet 3 of 25, drawn by C. Rock on 07/13/98. Labels added for the current location of the new gravity vault, old dome, new station, and spiral stairs (modified, image courtesy of P. Sullivan, pers. comm., 2008).

Figure 2.6: Theresa Diehl taking a gravity reading at the New South Pole station.

Figure 2.7: Another view into the recessed gravity station from 2004; Leo Peters from PSU is taking the gravity reading (photo courtesy of P. Sullivan, pers. comm., 2008)

3. Field Guide to Other Gravity Station Locations used in 2004-2005

SJB ZCM and SJB Willy: McMurdo Airport Locations

These two gravity locations were on floating ice, the first (ZCM) at the sea-ice runway at the beginning of the season and the second (Willy) at Williams Field on the ice shelf. Both were temporary locations and measurements were taken beneath the airplane in line with the airborne gravimeter. Both sites were difficult to take measurements at, especially ZCM) because the floating ice flexed due to nearby loads and readily transferred vibrations from other parts of the runway. These are the least trust-worthy gravity readings of the field season.

SJB THW: Thwaites Glacier Remote Field Camp 2004-2005

This gravity site was located at the remote field camp, though the exact position changed within a half-dozen meters in any direction depending on the where the plane was parked. Measurements were always taken under the plane, in line with the airborne meter. Since the metal plate used for leveling was kept inside a jamesway and was warmer than the ice, we had to put a flat piece of wood or cardboard beneath it to keep it from melting into the ice and becoming unleveled.

PNE: Pine Island Glacier Remote Field Camp 2004-2005

The Pine Island Glacier field camp station was well-located and stationary. The station consisted of a square, shallow trench in the snow with a “pier” of snow left in the center, about half the height of trench, on which to level the gravimeter. The trench was covered by a piece of wood to protect it from drifting and was located several meters away from the area where our Twin Otter parked for refueling. Establishing a semi-permanent base station like this one is preferable at field camps, compared to the method of measurements at Thwaites Glacier field camp.

4. Portable G-meter Gravity Readings

Over the course of the 2004-2005 AGASEA field season, three main operators (Theresa M. Diehl (TMD), Irina Y. Filina (IYF), and Erick Leuro (EL)) took gravity readings with a portable LaCoste & Romberg G-meter borrowed from the USGS. Janessa M. Link (JML) performed only one reading at the Thiel Station in McMurdo for the purpose of training her on the gravimeter. There were a total of 90 "average" readings taken over an 80 day span at a variety of station locations (Table 4.2). An "average" reading usually consists of three readings taken by a single operator at a location, where between each reading the gravimeter was clamped, un-leveled, re-leveled, and then re-read. This procedure provides an estimate of operator errors involved in the leveling and reading process. The operators established this procedure after Julian Day 320 and consistently followed it throughout the rest of the season. A complete field guide to the locations used for these gravity ties was presented in sections 1-3. Gravimeter readings in counter units were transformed into mGals using the information in Table 4.1. For example, a meter reading of 5732.7 CU (and thus, a base reading of 5700 CU) yields a gravity reading of 5973.67 such that: 5939.59 mGal + (1.04210 * (5732.7 CU - 5700 CU) = 5973.67 mGal.

Table 4.1: Conversions from counter units (CU) to milliGal (mGal)

Base Reading (CU)	Base Reading (mGal)	Interval Factor
5700	5939.59	1.04210
5800	6043.80	1.04190
6300	6564.57	1.04085

Table 4.2: Gravity Tie Data

Location	Year	Julian Day	Operator	Julian Day & Time	Average Reading (CU)	Gravity (mGal)	Reading Precision (mGal)
Thiel	2004	319	IYF	319.251	6351.75	6618.43	-
Thiel	2004	319	TMD	319.256	6351.85	6618.54	-
Seismic	2004	319	IYF	319.270	6351.52	6618.19	-
Seismic	2004	319	TMD	319.274	6351.59	6618.27	-
Hut Pt BC-4	2004	320	IYF	320.271	6356.68	6623.57	-
Hut Pt BC-4	2004	320	TMD	320.274	6356.88	6623.77	-
Thiel	2004	323	IYF	323.256	6351.75	6618.43	0.03
Thiel	2004	323	TMD	323.261	6351.78	6618.46	0.01
Seismic	2004	323	IYF	323.269	6351.51	6618.18	0.01
Seismic	2004	323	TMD	323.275	6351.45	6618.13	0.02
Thiel	2004	323	IYF	323.281	6351.79	6618.48	0.02
Thiel	2004	323	TMD	323.285	6351.77	6618.45	0.01
Hut Pt BC-4	2004	323	TMD	323.304	6356.85	6623.75	0.02
Hut Pt BC-4	2004	323	IYF	323.309	6356.90	6623.80	0.01
Thiel	2004	323	TMD	323.328	6351.87	6618.55	0.01
Thiel	2004	323	IYF	323.333	6351.82	6618.50	0.02
SJB ZCM	2004	323	TMD	323.379	6332.96	6598.88	0.16
SJB ZCM	2004	323	IYF	323.384	6332.87	6598.78	0.05
Thiel	2004	323	IYF	323.422	6351.87	6618.56	0.01
Thiel	2004	323	TMD	323.427	6351.87	6618.56	0.01
Thiel	2004	323	IYF	323.748	6351.85	6618.54	0.00
Thiel	2004	323	TMD	323.752	6351.84	6618.53	0.02
Old S. Pole	2004	324	TMD	324.026	5721.00	5961.48	0.01
Old S. Pole	2004	324	IYF	324.030	5721.01	5961.48	0.01
New S. Pole	2004	324	TMD	324.052	5722.56	5963.10	0.00
New S. Pole	2004	324	IYF	324.055	5722.60	5963.14	0.00
Thiel	2004	324	IYF	324.231	6351.83	6618.52	0.03
Thiel	2004	324	TMD	324.237	6351.85	6618.54	0.02
Thiel	2004	328	TMD	328.025	6351.75	6618.44	0.02
Thiel	2004	328	EL	328.034	6351.75	6618.43	0.03
Seismic	2004	328	EL	328.046	6351.45	6618.13	0.03
Seismic	2004	328	TMD	328.050	6351.49	6618.16	0.01
Thiel	2004	328	EL	328.058	6351.61	6618.28	0.29
Thiel	2004	328	TMD	328.061	6351.79	6618.48	0.02
Hut Pt BC-4	2004	328	TMD	328.075	6356.72	6623.61	0.01
Hut Pt BC-4	2004	328	EL	328.084	6356.73	6623.61	0.03
Thiel	2004	328	TMD	328.095	6351.74	6618.43	0.04
Thiel	2004	328	EL	328.105	6351.73	6618.41	0.03
SJB ZCM	2004	328	TMD	328.148	6332.86	6598.77	0.06
SJB ZCM	2004	328	EL	328.154	6332.95	6598.87	0.09
Thiel	2004	328	EL	328.179	6351.72	6618.40	0.02
Thiel	2004	328	TMD	328.183	6351.77	6618.46	0.01
Thiel	2004	331	TMD	331.237	6351.69	6618.37	0.01

Location	Year	Julian Day	Operator	Julian Day & Time	Average Reading (CU)	Gravity (mGal)	Reading Precision (mGal)
Thiel	2004	331	EL	331.241	6351.71	6618.39	0.01
SJB ZCM	2004	331	EL	331.261	6332.12	6598.00	0.68
SJB ZCM	2004	331	TMD	331.266	6332.73	6598.64	0.05
Thiel	2004	331	TMD	331.289	6351.73	6618.41	0.01
Thiel	2004	331	EL	331.293	6351.70	6618.38	0.00
Thiel	2004	336	EL	336.210	6351.68	6618.36	0.02
Thiel	2004	336	TMD	336.214	6351.74	6618.42	0.00
Thiel	2004	337	EL	337.872	6351.74	6618.42	0.03
Thiel	2004	337	TMD	337.876	6351.78	6618.47	0.01
Seismic	2004	337	TMD	337.881	6351.37	6618.04	0.01
Seismic	2004	337	EL	337.892	6351.37	6618.04	0.01
Thiel	2004	337	EL	337.898	6351.72	6618.40	0.02
Thiel	2004	337	TMD	337.902	6351.78	6618.47	0.01
Hut Pt BC-4	2004	337	EL	337.921	6356.75	6623.64	0.01
Hut Pt BC-4	2004	337	TMD	337.926	6356.77	6623.66	0.01
Thiel	2004	337	TMD	337.938	6351.77	6618.46	0.01
Thiel	2004	337	EL	337.942	6351.77	6618.45	0.00
Thiel	2004	338	JML	338.081	6351.73	6618.42	0.03
Thiel	2004	338	TMD	338.084	6351.77	6618.46	0.01
Thiel	2004	338	EL	338.088	6351.73	6618.41	0.02
SJB ZCM	2004	338	TMD	338.109	6332.67	6598.57	0.09
SJB ZCM	2004	338	EL	338.117	6332.73	6598.63	0.02
Thiel	2004	338	EL	338.134	6351.73	6618.41	0.01
Thiel	2004	338	TMD	338.145	6351.75	6618.44	0.01
Thiel	2004	344	EL	344.845	6351.50	6618.17	0.27
Thiel	2004	344	TMD	344.850	6351.70	6618.38	0.01
SJB Willy	2004	344	TMD	344.889	6310.24	6575.23	0.12
SJB Willy	2004	344	EL	344.905	6310.35	6575.34	0.09
Thiel	2004	344	TMD	344.959	6351.70	6618.39	0.01
Thiel	2004	344	EL	344.968	6351.72	6618.40	0.03
SJB THW	2004	347	EL	347.451	5883.76	6131.07	0.06
SJB THW	2004	347	TMD	347.456	5883.85	6131.16	0.02
SJB THW	2004	354	TMD	354.984	5883.76	6131.07	0.03
SJB THW	2004	354	EL	354.986	5883.81	6131.12	0.02
PNE	2004	355	TMD	355.164	5849.54	6095.42	0.02
SJB THW	2004	355	TMD	355.347	5883.80	6131.11	0.01
SJB THW	2004	365	TMD	365.025	5883.61	6130.91	0.01
SJB THW	2004	365	EL	365.284	5883.79	6131.10	0.05
PNE	2005	2	TMD	2.994	5849.40	6095.27	0.01
SJB THW	2005	8	TMD	8.081	5883.51	6130.81	0.01
SJB THW	2005	8	EL	8.085	5883.65	6130.95	0.01
PNE	2005	19	TMD	19.982	5849.53	6095.41	0.01
SJB THW	2005	21	EL	21.190	5883.73	6131.04	0.01
SJB THW	2005	22	TMD	22.910	5883.52	6130.82	0.01
SJB THW	2005	32	EL	32.862	5883.52	6130.82	0.02

Location	Year	Julian Day	Operator	Julian Day & Time	Average Reading (CU)	Gravity (mGal)	Reading Precision (mGal)
SJB THW	2005	32	TMD	32.867	5883.53	6130.83	0.02
Thiel	2005	33	EL	33.978	6351.69	6618.38	0.02
Thiel	2005	33	TMD	33.984	6351.73	6618.42	0.01

Gravimeter Drift Calculations, Absolute Gravity Determination, and Ties

Since the handheld and airborne gravity meters for this survey were relative instruments (measuring changes in gravity, not the absolute value of gravity), they were calibrated by tying their counter values to a base station of known absolute gravity value. At McMurdo the only station with a "known" gravity value was the Thiel station, which was tied to the IGSN71 network (see Section 1 for station information). Therefore, the three main G-meter operators took 44 readings at the Thiel station, with 42 of those readings occurring before the put-in to THW remote field camp and two occurring in the limited three days the field party had at McMurdo post-season.

The total length of each timeseries at Thiel varies by operator, but all three operators' readings cluster within a rage of only 0.5 mGal, including both pre- and post- field operations (Figure 5.1). Therefore, there were no tares in the G-meter data during the four-month field season. Using all the Thiel data points and assuming a linear fit, the drift rate would be 0.0016 mGal/dy and would produce a total 0.128 mGal drift over the 80 days of measurement (Figure 4.2). I also calculated a G-meter drift rate for the TMD timeseries at the THW field camp. At 0.0073 mGal/dy, the total drift would be 0.3723 mGal over the 51 days of G-meter measurements at THW field camp (Figure 4.3). Both calculated drift rates are too small to be significant and are thus negligible considering the accuracy of airborne surveys is generally several (1-4) mGal. So, no G-meter drift correction was needed. I performed a similar analysis with the Micro-g LaCoste Air/Sea II average still readings taken throughout field operations and also found a negligible drift rate for that meter.

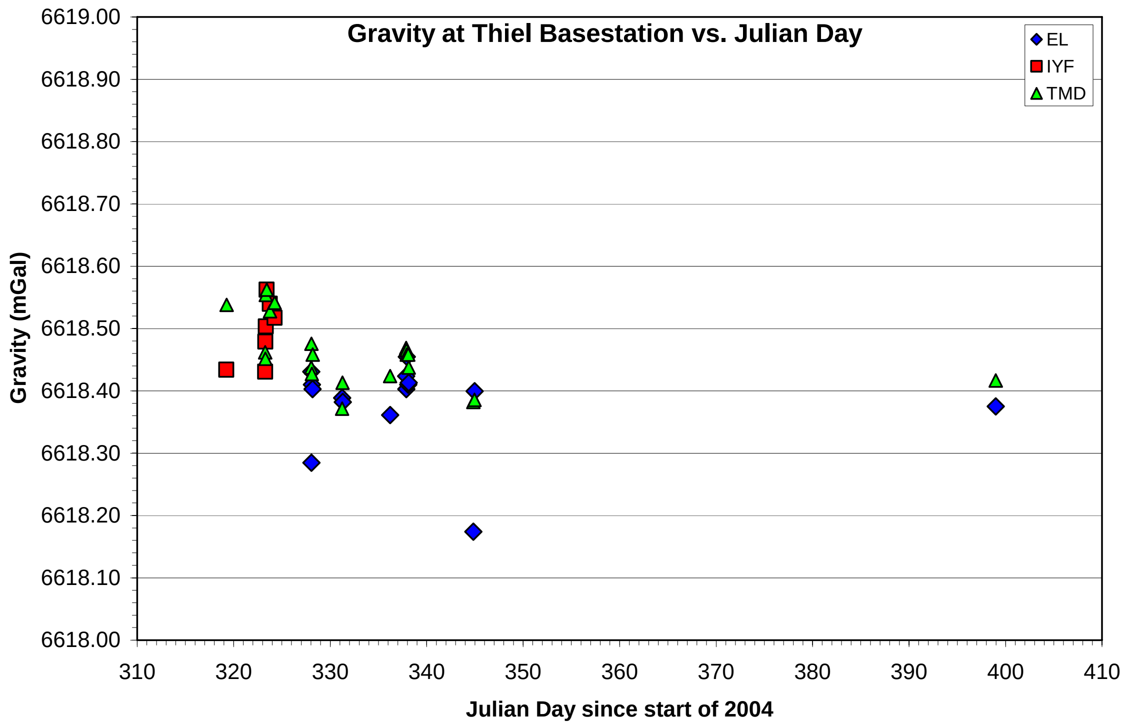


Figure 4.1: Gravity readings in mGals at the Thiel basestation in McMurdo over the course of the 2004-2005 AGASEA season, for three operators.

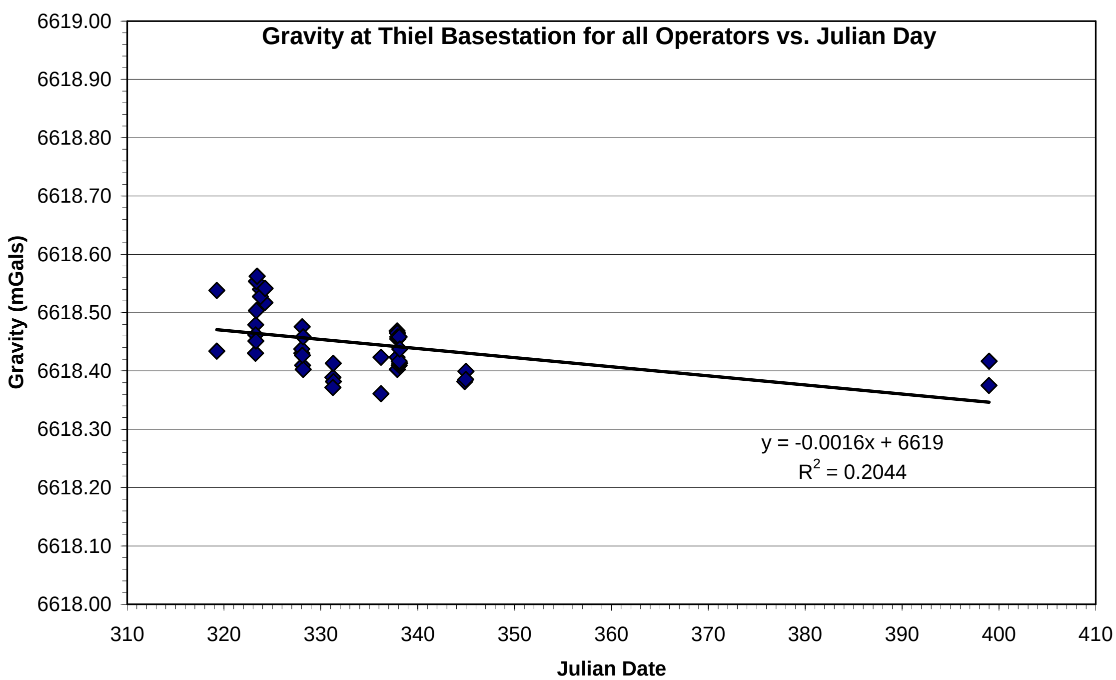


Figure 4.2: Same as Figure 4.1 but with best-fit drift rate.

Of the three series available at McMurdo's Thiel station, those from TMD and EL have readings both before and after field operations. But TMD's series is the longest, therefore I used the average of the TMD data points at Thiel station to calculate the offset between the G-meter gravity reading and absolute gravity (Table 4.3, column 1): 976351.27 mGals. I then applied this offset to the average TMD readings at THW and PNE temporary field camp stations in order to tie the still reading of the Micro-g LaCoste Air/Sea II gravimeter (at THW, Figure 4.4) and the gravimeters used during the British Antarctic Survey's field season (at PNE) (Table 4.3). The offsets I calculated from the UTIG ties are being used for the British Antarctic Survey's datasets preferentially over their own ties due to UTIG's slightly shorter time between Thiel base station measurements and access to a more recent absolute gravity value reading in McMurdo than those available for Rothera's gravity station (T. A. Jordan, pers. comm., 2007); [*Jordan, et al.*, submitted].

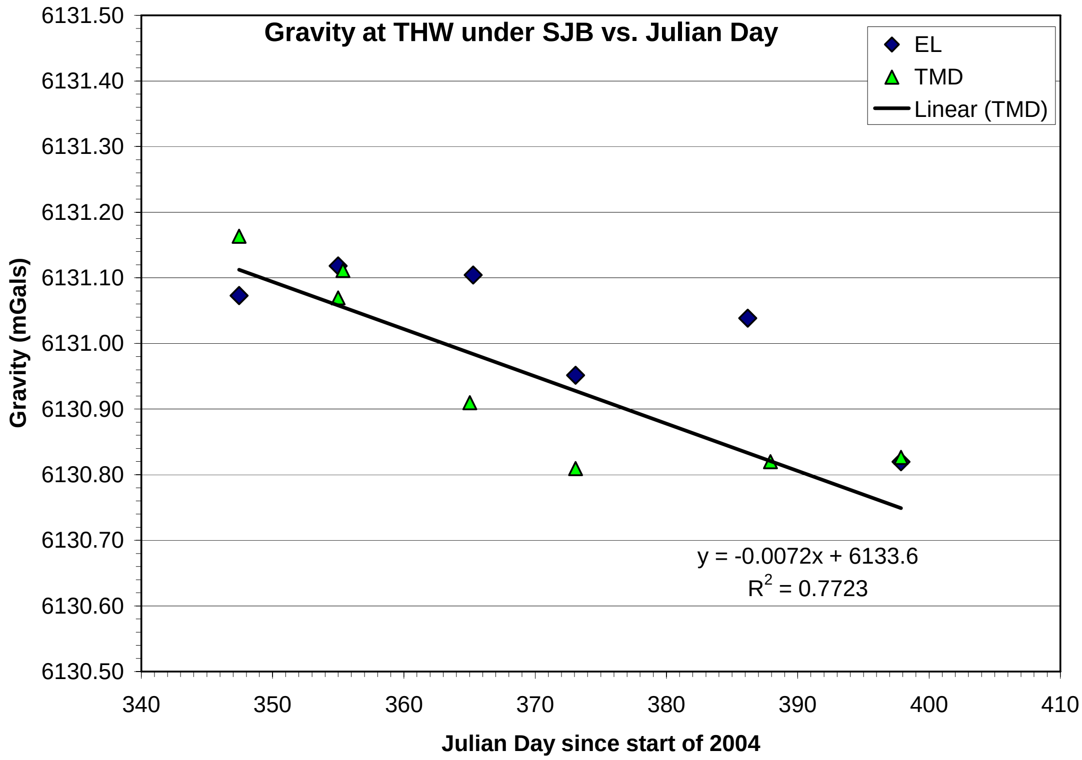


Figure 4.3: Handheld gravimeter readings at the Thwaites remote field camp.

Table 4.3: Absolute gravity at three stations, tied to IGSN71

	Thiel (McMurdo) TMD Average	THW TMD Average	PNE TMD Average
G-meter Gravity Reading (mGals)	6618.46	6130.96	6095.41
IGSN71 Absolute Gravity (m/s2)	9.829697277	9.824822263	9.824466819
IGSN71 Absolute Gravity (mGals)	982969.7277	982482.2263	982446.6819
Air/Sea II Still Gravity Reading (mGals)	-	13914.16	-

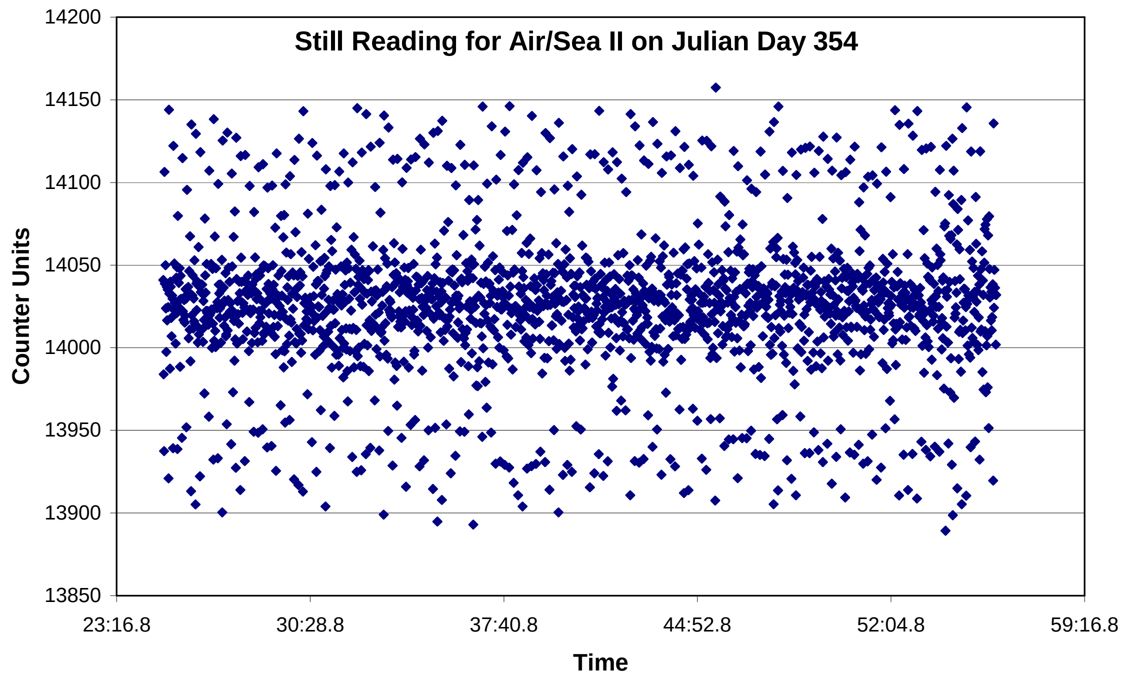


Figure 4.4: Still reading for the Air/Sea II airborne gravimeter (raw counter units sampled at 1 Hz) over 30 min on Julian Day 354 (coincident in time and location with handheld gravimeter readings), the average 14026.37 CU from this still reading equates to 13914.16 mGals when adjusted for the gravimeter's scaling factor.