Gravity Measurements in South Island New Zealand Feb 2000

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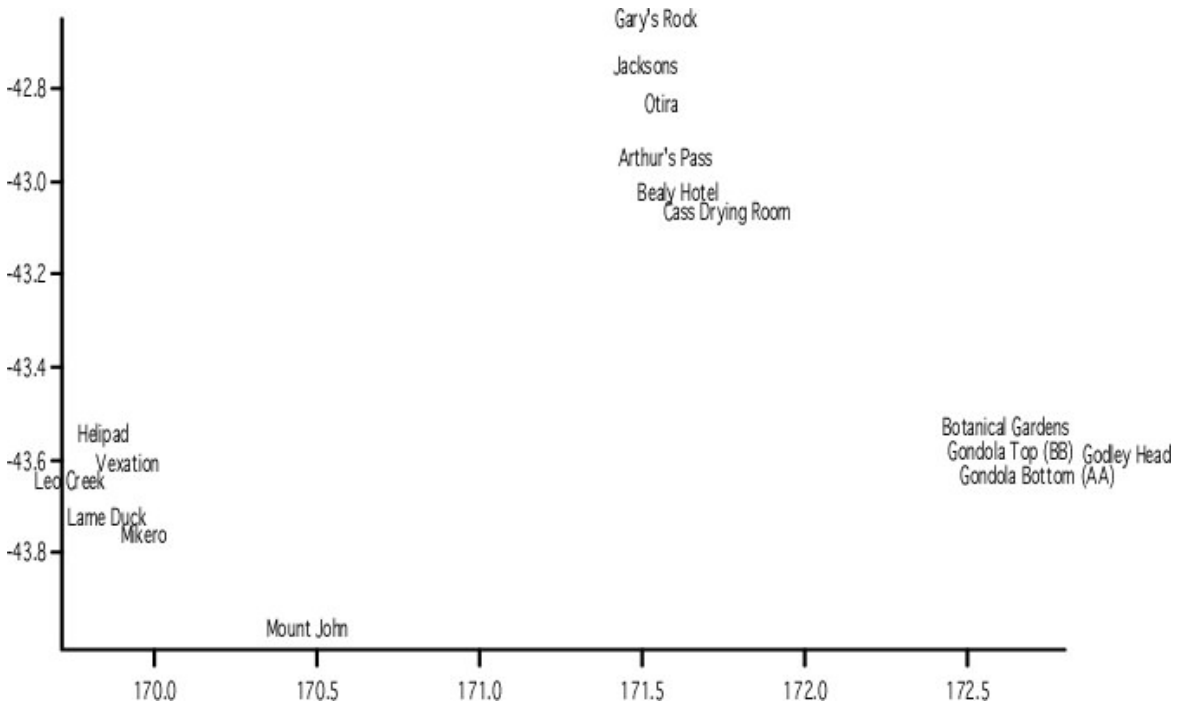
During the month of February 2000 the acceleration due to gravity was measured at 16 sites in New Zealand using an FG5 Absolute gravimeter (#111). Two transects were selected: one across Arthurs Pass towards Christchurch (10 measurements), and the other in a remote region of rough terrain south of Fox glacier (6 measurements). Of the 10 Christchurch measurements 4 were undertaken near the city to provide calibration and datum control to the New Zealand gravity network. Measurement durations ranged from a few hours to 24 hours, yielding typically <2 µgal standard deviation data, except at two locations where high amplitude low frequency oscillations were encountered in thick sedimentary basins. The data were corrected for tides, and direct atmospheric loading but not for subsurface water level, due to the absence of bore-holes. Relative gravity was re-measured to 10 µgal accuracy using a LaCoste Romberg D-17 gravimeter along a line of 15 bench marks across Arthurs Pass (previously measured in 1978).

Table 1 Absolute Gravity Measurements New Zealand

Site Name	Latitude	Longitude	Grad.	Std Press	Date	g@ 1m	g@ 0m	error
				mb		µGal		
Gondola Top	-43.588	172.716	3.81	960.92	2/9/00 9:27	980 421 716.2	980 422 097.2	1.39
Arthur's Pass	-42.95	171.57	2.33	928.27	2/13/00 5:24	980 229 009.9	980 229 242.9	1.20
Bealy Hotel	-43.02	171.61	2.73	939.93	2/12/00 10:23	980 261 187.8	980 261 460.6	0.30
Botanical Gdns	-43.53	172.62	3.60	1012.53	2/7/00 8:38	980 493 985.3	980 494 345.3	5.10
Cass	-43.035	171.759	3.05	943.20	2/11/00 13:08	980 272 118.5	980 272 423.5	0.50
Gary's Rock	-42.649	171.54	4.41	998.92	2/20/00 15:30	980 359 858.8	980 360 299.9	0.95
Otira	-42.832	171.56	2.11	951.64	2/14/00 12:53	980 291 981.4	980 292 192.4	0.24
Gondola low	-43.588	172.716	2.95	1004	2/8/00 0:57	980 505 179.9	980 505 474.9	0.92
Leo Creek	-43.643	169.737	-5.15	869.27	2/18/00 4:23	980 188 398.4	980 188 913.4	0.44
Mount John	-43.987	170.465	-3.91	896.4	2/10/00 15:55	980 248 544.6	980 248 935.6	0.34
Helipad	-43.539	169.839	-2.92	1004.87	2/19/00 2:08	980 439 547.4	980 439 839.3	2.01
Godley Head	-43.588	172.804	-3.60	998.32	2/5/00 4:24	980 489 154.1	980 489 514.1	0.80
Jacksons	-42.747	171.51	2.79	980.06	2/15/00 12:08	980 336 050.9	980 336 329.9	1.00
Lame Duck	-43.72	169.85	4.86	832.16	2/17/00 22:56	980 091 624.6	980 092 110.6	0.63
Vexation	-43.637	169.893	4.4	850.76	2/17/00 0:56	980 131 601.1	980 132 041.1	1.01
Mikero	-43.73	169.98	4.4	802.88	2/17/00 9:24	980 038 648.7	980 038 208.7	0.41

The data are archived on CD (200 Mb raw files). The data have been corrected for body tides and load tides calculated by Olivier Francis. No tidal residuals are evident in the processed gravity data.

The gravimeter was moved between the Arthur's Pass points by road and was moved between summit points via helicopter. A special lightweight tent was developed that could be fixed to rock using eight 1/8" hammer drilled holes. The system was slung beneath the helicopter and moved in three hops. The first carried one person and relative gravity equipment. Prior to arrival of the second load (the gravimeter itself) the gravity gradient was measured at two levels above the measurement pad. The third load brought two more people, and camping gear. The equipment was set up within the space of one hour. Measurements continued for 3-10 hours although no substantial improvement in the gravity value was obtained after 2 hours.


Gary's Rock
Jacksons
Otira
Arthur's Pass
Bealy Hotel
Cass Drying Room
Botanical Gardens
Gondola Top (BB)
Gondola Bottom (AA)
Godley Head
Helipad
Vexation
Leo Creek
Lame Duck
Mikero
Mount John
-42.8
-43.0
-43.2
-43.4
-43.6
-43.8
170.0
170.5
171.0
171.5
172.0
172.5

Calibration of relative-g meter D17

The top and bottom calibration points at Mt. Cavendish near Christchurch were occupied sequentially by LaCoste gravimeter number D-17 using the Gondola to transport the instrument between the two locations. The procedure adopted in the calibration was to first check the electronic calibration against the mechanical calibration. This agreed with the previous calibration constant to within 1% (approximately unity). Then the difference between the top and bottom calibration marks was calculated using the old mechanical calibration. The gravimeter was transported 3 times up and down the mountain setting the large dial to integer units (1-10) and allowing the electronic output to provide the indicated value over several minutes. Finally the resulting inferred gravity difference was divided by the absolute gravity difference measured with the FG5.

Table 1 Old calibration values

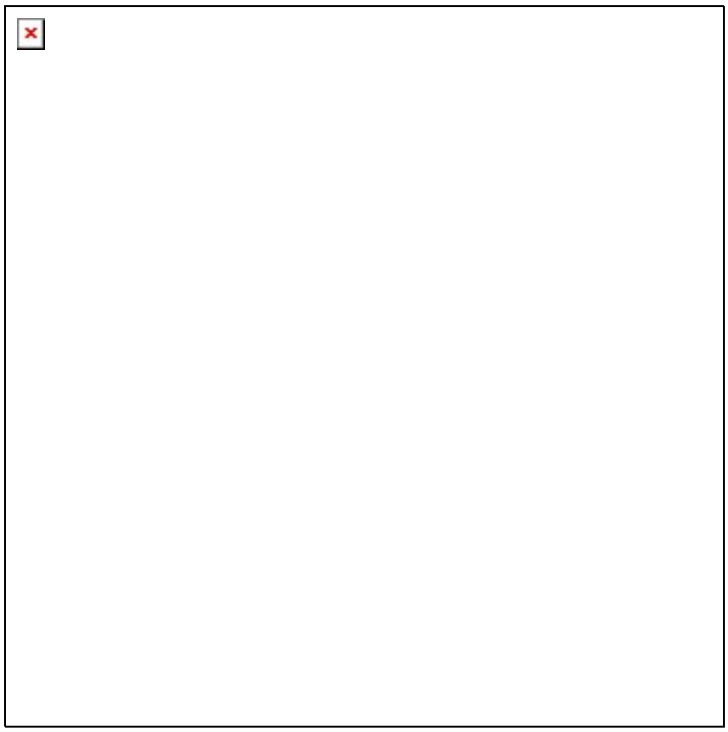
Old Calibration Meter D-17:
Mechanical Adjustment (Screw range: 0 to 200)
The large wheel has 10 divisions each with ten marks which can be read to 1/10 division.
Screw scale factor 1.36625 mGal/unit full turn
gravity range: 273 mGal
Electronic adjustment. EFU range: about -1.7 to +1.7
EFU scale factor: 0.98483 mgal/EFU unit
gravity range: 3.3 mGal

Table 2 Calibration Observations at the top and base of the Gondola on Mt. Cavendish, NZ.

				OBSERVED DATA			Calc g	drift/day	g-drift		
calibration	Date and time	day	scale	servo	servo correction	tide µg	{sc+elec }*cal-tide	0.2196 mGal/d	corrected	Average gravity	STDEV
base	23/2/00 23:47	54.991	15771	0.009	0.009	22	215.46	0.000	215.458	215.458	
top	24/2/00 0:06	55.004	9660	0.06	0.059	15	132.02	0.003	132.021	131.982	0.027
top	24/2/00 0:13	55.009	9660	0	0.000	13	131.97	0.004	131.963		
top	24/2/00 0:14	55.010	9660	0.004	0.004	13	131.97	0.004	131.967		
top	24/2/00 0:15	55.010	9660	0.013	0.013	12	131.98	0.004	131.976		
base	24/2/00 0:32	55.022	15767	0.038	0.037	5	215.45	0.007	215.442	215.442	0.002
base	24/2/00 0:33	55.023	15767	0.04	0.039	5	215.45	0.007	215.444		
base	24/2/00 0:35	55.024	15767	0.037	0.036	4	215.45	0.007	215.442		
base	24/2/00 0:36	55.025	15767	0.034	0.033	4	215.45	0.007	215.439		
top	24/2/00 0:46	55.032	9660	0.013	0.013	1	131.99	0.009	131.983	131.989	0.007
top	24/2/00 0:47	55.033	9660	0.018	0.018	1	132	0.009	131.987		
top	24/2/00 0:48	55.033	9660	0.022	0.022	0	132	0.009	131.992		
top	24/2/00 0:50	55.035	9660	0.027	0.027	-1	132.01	0.010	131.998		
top	24/2/00 0:52	55.036	9660	0.027	0.027	-1	132.01	0.010	131.997		
top	24/2/00 0:54	55.037	9660	0.01	0.010	-2	131.99	0.010	131.981		
top	24/2/00 0:55	55.038	9660	0.011	0.011	-2	131.99	0.010	131.982		
base	24/2/00 1:08	55.047	15770	-0.02	-0.015	-6	215.45	0.012	215.436	215.431	0.010
base	24/2/00 1:16	55.053	15770	-0.01	-0.012	-9	215.45	0.014	215.441		
base	24/2/00 1:23	55.058	15770	-0.02	-0.017	-11	215.45	0.015	215.437		
base	24/2/00 1:33	55.065	15770	-0.03	-0.028	-13	215.44	0.016	215.427		
base	24/2/00 1:40	55.069	15770	-0.03	-0.029	-15	215.44	0.017	215.427		
base	24/2/00 1:48	55.075	15770	-0.04	-0.041	-17	215.43	0.018	215.415		
top	24/2/00 2:04	55.086	9660	0.012	0.012	-20	132.01	0.021	131.991	131.982	0.013
top	24/2/00 2:11	55.091	9660	0.019	0.019	-21	132.02	0.022	131.997		
top	24/2/00 2:17	55.095	9660	-0.01	-0.014	-22	131.99	0.023	131.965		
top	24/2/00 2:21	55.098	9660	-0	-0.002	-23	132	0.023	131.977		
top	24/2/00 2:25	55.101	9660	-0	-0.002	-24	132	0.024	131.978		
base	24/2/00 2:41	55.112	15764	-0.01	-0.005	-24	215.39	0.027	215.368	215.369	-0.001
base	24/2/00 2:42	55.113	15764	-0	-0.003	-24	215.4	0.027	215.370		

The combined load and body tide was provided by Olivier Francis and is show in the graph below. Four hours of values in μGal are shown and the vertical lines are at ten minute intervals.

Figure 1 Gravity tide calculated for 43.6° South, 172.7 °East .



From the several readings at the top and bottom, the gravity difference using the old calibration is next compared to the absolute difference as derived by the FG5 gravimeter. The relative gravity difference measured between the lower point and the upper point is 83.455±0.002 mgal (Table 3).

Table 3. Absolute values for the Calibration Base Feb 2000.

Site Name	Latitude	Longitude	Gradient	Std Press	Date	g@ 1m	g@ 0m	error
GondolaTop	-43.588	172.716	3.81	960.92	9/2/00 9:27	980421716.2	980422097.2	1.39
Gondola Base	-43.588	172.716	2.95	1004	8/2/00 0:57	980505179.9	980505474.9	0.92

Table 4. Comparisons between relative and absolute observations. Note the first and last values are obtained from fewer measurements than the central five measurements.

rel gravity	stdev	g-difference	ratio to abs	Ave. date/time
215.4582				2/23/00 23:47
131.9816	0.026808	83.47651	1.001185	2/24/00 0:12
215.4417	0.00223	83.46001	1.000987	2/24/00 0:34
131.9887	0.007126	83.45298	1.000903	2/24/00 0:47
215.4306	0.009689	83.4419	1.00077	2/24/00 1:20
131.9816	0.012666	83.44894	1.000854	2/24/00 2:13
215.3691	0.001285	83.38745	1.000117	2/24/00 2:41
Absolute-g		83.455		
Average observed		83.445	1.0008	
Standard deviation		0.0304	0.00036	
Average mid- five only		83.45096	1.000879	
		0.007573	0.00009	

The first and the last measurements which used only one or two observations obtained in a few minutes, are seen to deviate from the sets of measurements that included four or more observations over a period of several minutes. Two estimates are obtained: the first includes all the data and shows the old calibration to be 1.0008±0.0004 times too high, and the second including the central subset of the data indicates that the old value is 1.0009±0.0001 times too high.

From the central set of five measurements a correction factor of 1/1.0009 is applied to the old calibration factor of 1.36625 mGal/unit full turn, to yield a new calibration factor of **1.3653** mgal/turn (0.013653 mgal/dial unit)

Thus, for the February measurements, the scale calibration factor used for reducing the field observations was 0.013653 mGal per instrument-unit.

Accuracy of field observations at the Mt Cavendish Calibration Base

The average standard deviation of a cluster of measurements at Mt Cavendish is 12 µgal (Table 2), varying from 2 –27 µgal if the gravimeter is not moved between measurements. This suggested that at this site it is not usually possible to read relative-g to better than 12 µgal and sometimes to no better that 30 µGal. A suite of measurements over 10 minutes appears to be desirable.

In other locations where we used relative-g between absolute g points we found that sometimes the calculated value differed from the absolute value by 50 µGal. We thus do not claim a higher accuracy than 50 µgal for any of the relative g points. This is a factor of 4 worse than the New Zealand g measurements of 1985.

Measurements of Relative Gravity in South Island New Zealand

The following map shows the locations of relative gravity points measured using a LaCoste gravimeter. These points were first measured 15 years previously. The trend of the Alpine Fault in map view is shown as a dotted line in this figure and 60 cm of relative uplift occurs near the center of the pass. This is partly caused by secular motions and partly by the Arthurs Pass earthquake of 1993.