

Changes in absolute Gravity 2000-2015, South Island, New Zealand

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Supplementary materials:

Operational narrative for sites occupied in December 2014 and January 2015

Numerical values for each set of 100 drops from each site are listed in spreadsheets in folders with station names as indicated.

#	location	page	Data folders with raw set data
1.	Godley Head	2	Feb 2000, Dec 2014, Jan 2015
2.	Gondola Bottom Station	6	Gondola top and bottom
3.	Gondola Top Station	8	Gondola top and bottom
4.	Botanical Garden	10	Botanical Garden
5.	Cass	12	Cass Dec and Jan
6	Bealey Hotel	14	Bealey Hotel Gary
7.	Arthurs Pass Jail	16.	Arthurs Pass
8.	Heli (James Scotts Hanger)	18	Heli
10	Makawhio	21	Makawhio
11.	Vexation	23	Vexation
12.	Gary's Rock	25	Gary
13	Jackson's Garage	28	Jackson
14.	Mt John	30	Mt John
15	Leo Creek	33.	Leo Creek
16.	Otira (not occupied)		Otira
17.	McKerrow (point obscured by ice)		

1. Godley Head, measurements



View south of Godley Head from north (New Brighton). Site is amid trees on central headland. The tidal attraction around the headland resulted in a measured tidal variation of gravity both in 2000 and 2015..

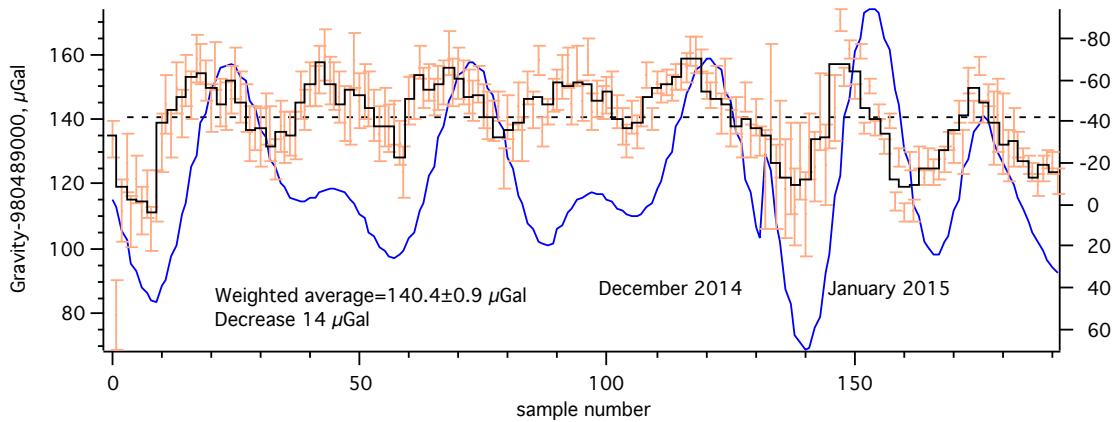


View of the measurement hut at Godley head.

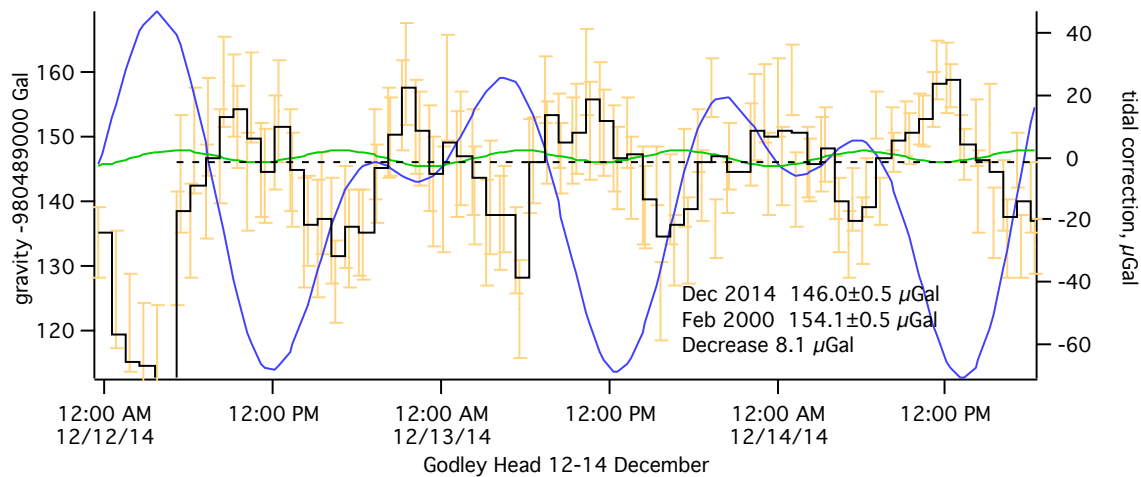
Notes After extraction from customs the vacuum was pumped down for 48 hours in Christchurch and shifted to Godley Head on 10 Dec. A detached board in the Magma fringe counter was fixed. Between Godley head and the next site(Gondola base) the power cable to the laser supply fell out of the back of the sub-assembly. After every sequence of sets the system was aligned vertical to within ± 0.3 bubble divisions and to within one spot diameter. Although the coarse level was set to zero, the lower precision bubbles were not adjusted to zero. Drift was typically less than 1 division during a 12 hour sequence. Fringe amplitude was adjusted to $350\text{mV} \pm 15\text{ mV}$. The superspring has automatic adjustment but was checked to be close to zero. Vacuum ion pump voltage 4kV and $0.42\text{-}0.5 \times 10^{-4}$ throughout. Height offset measured was 14.92 cm in subsequent processing. Four data sets were acquired and processed with the corrected times. A residual $25\ \mu\text{Gal}$ tide is evident. The ensemble average is a weighted least-squares fit with zero slope omitting the first set :

Name	#sets	Value μGal	time offset
GodleyHead 13Dec2014A	10	980489115.79 ± 4.5	+01:51
GodleyHead 13Dec2014B	48	980489144.4 ± 2	+01:51
GodleyHead 14Dec2014	32	980489144.7 ± 1.3	0
GodleyHead 15Dec2014	42	980489147.3 ± 1.1	0
Ensemble average	132	980489146.0 ± 0.5	
Feb2000 value		980489154.1 ± 0.5	

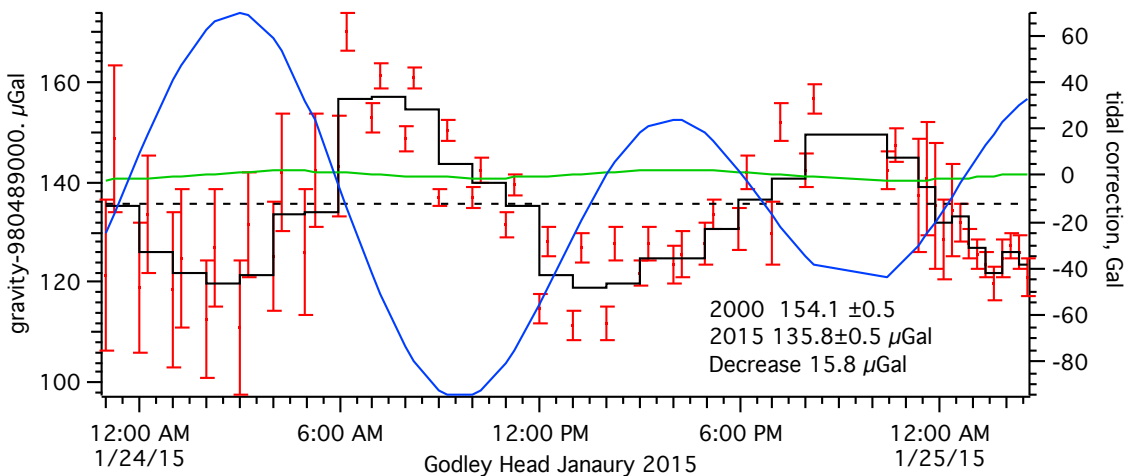
24 January 2015	44	980489137.8	+2 s
Decrease Dec 2014		8.1	± 0.5
Decrease Jan 2015		15.8	± 0.5
Decrease dec/jan ave		14.1	± 0.5



All the data shown as 191 sequential sets. Residual tide is related to lunisolar attraction of surrounding sea (body tide axis is reversed in this plot)

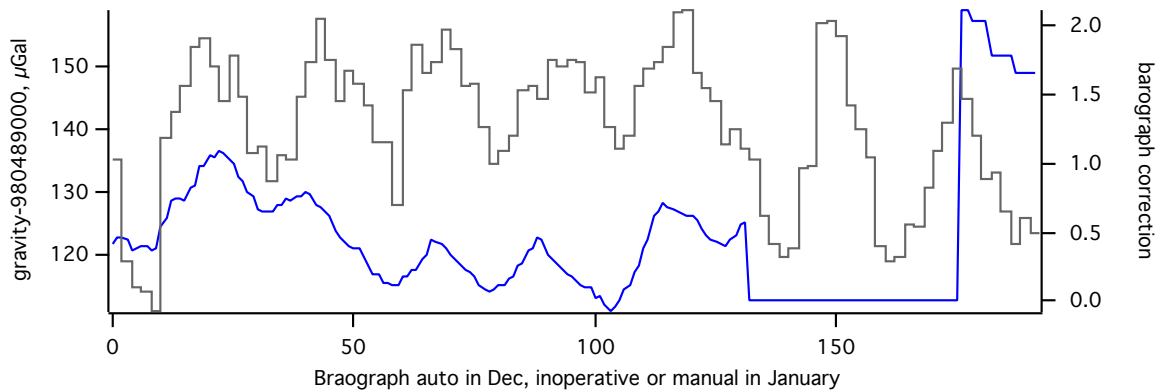


Godley Head data 12-14 Dec 2014. Decrease $8.1 \pm 1 \mu\text{Gal}$ (but lower precision bubbles not checked)



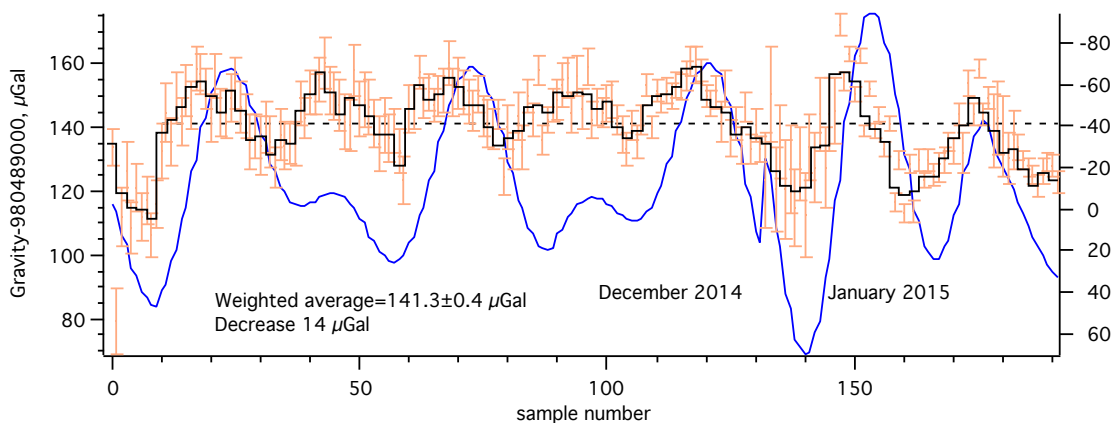
An Australian team measured the same point on 28 January and derived a value of $135.2 \pm 5 \mu\text{Gal}$

Air pressure considerations



The nominal pressure entered in 2000 and during 1014/15 was 980.32 mb corresponding to an elevation of 125 m. The barometer was operating correctly in December, but for the 24 January data the barometer was inoperative (straight line above). This was noticed on the 25th and manual readings were taken for the last four hours of data. The measurements correspond to the 4th day of a 4 day high pressure over NZ at the time so that the values suggest the observed gravity for January should be reduced by 1.7-2.1 μGal . An average of 1.9 μGal was used in Fig 4 assuming that the measured values were reasonably representative for the previous day.

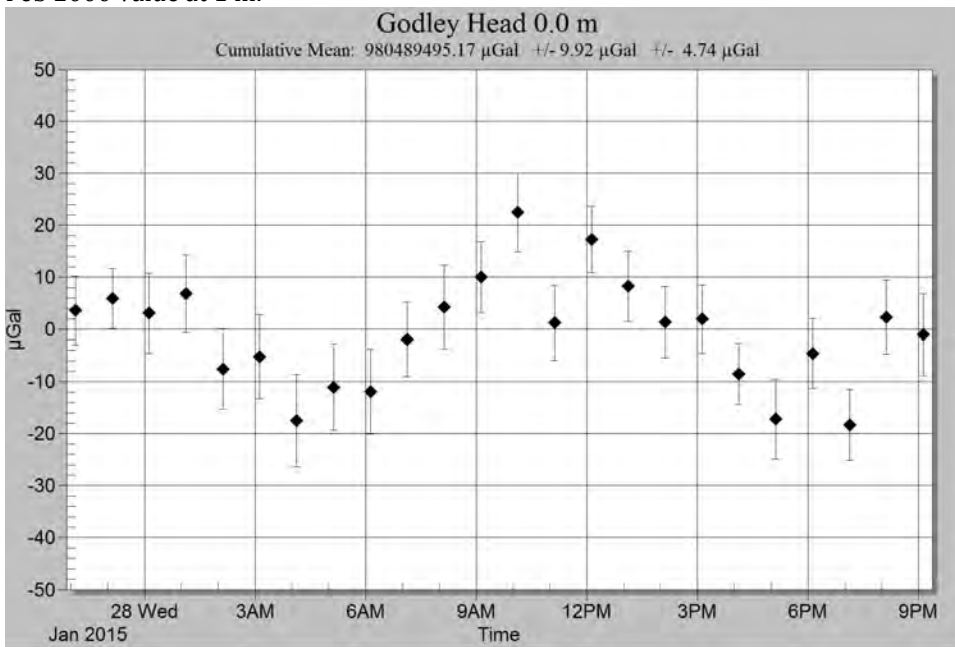
date and time UT	volts	mb	LOCATION	mb corr	$\mu\text{gal corr}$
01/24/2015 21:16:00	3.743	1005.375	Godley 998.32	7.055	2.1165
01/24/2015 22:35:00	3.741	1005.125	Godley 998.32	6.805	2.0415
01/25/2015 00:22:00	3.734	1004.25	Godley 998.32	5.93	1.779
01/25/2015 01:32:00	3.731	1003.875	Godley 998.32	5.555	1.6665



The January data have been increased by 1.9 μGal to compensate for manually observed atmospheric pressure not removed during field processing. The average value is 13 ± 2 μGal below the 2000 value. An improved value may be possible after tidal correction using tide gage data from local harbors.



The Godley head floor plaque in Feb 2000 (156) indicates a “0 m” value 2 μGal higher than the final Feb 2000 value at 1 m.

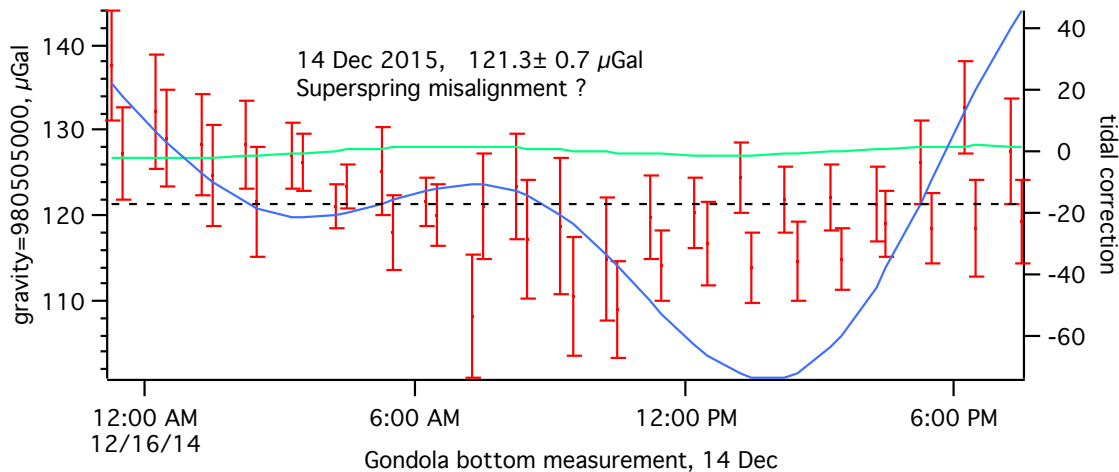


Measurements from Australian FG5-237 operated by Nick Dando forwarded by Vaughan Stagpole measured 28 January indicate $495.17 \pm 5 \mu\text{Gal}$ at 0 m = $144.17 \pm 3 \mu\text{Gal}$ at 1 m with a newly measured gradient of $-3.51 \mu\text{Gal}/\text{cm}$

2. Gondola Bottom station

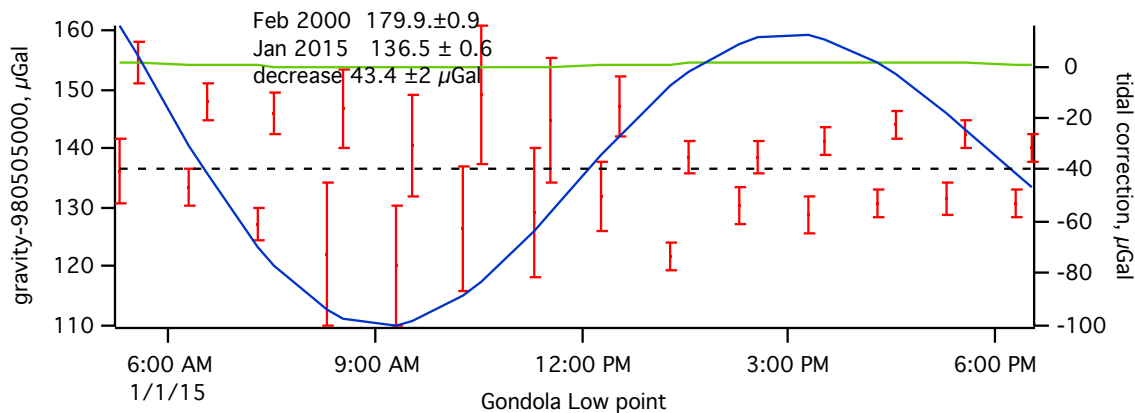
-43.588°S, 172.716°E, Elevation 77.3m gradient -2.95 $\mu\text{Gal}/\text{com}$
 2000 value was 980 505 179.9 \pm 0.92. Decrease 43.4G al.

14 Jan 2015 value adopted 136.0 \pm 0.8 μGal , 136.5 \pm 0.6 lsf μGal



16 Dec decrease 53.5 μGal

Dipstick 7.4 cm +upper 8.05 cm Height entered 15.45 cm Vacuum start 0.40. Data suspect because lower precision levels may have been misaligned and the superspring magnet became detached at about this time.



24 January Decrease 43.4 μGal i.e. identical to Gondola top

The point lies to the left of the rear entrance to the building that hosts the machinery for operating the Gondola. A small storage room with a staircase leading to an upper storage room is found on the north side of the building. The point is at the base of the stairs.

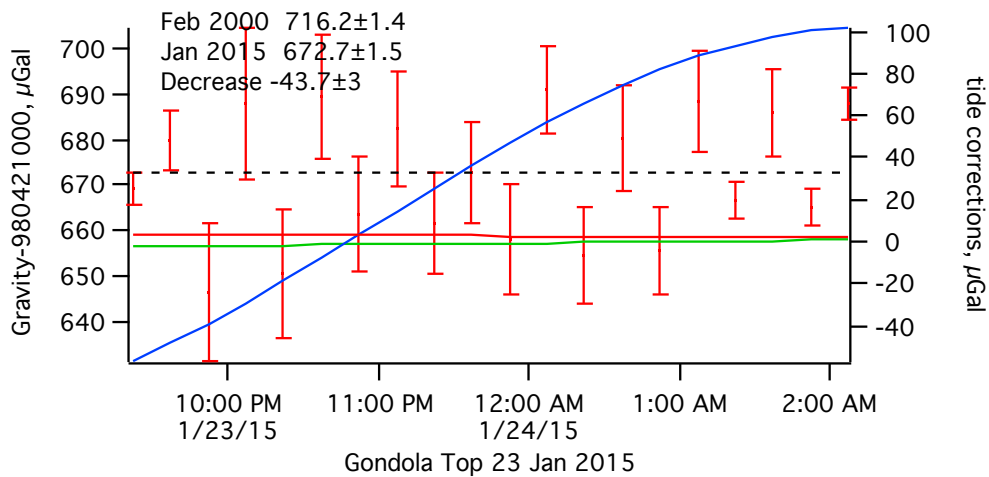
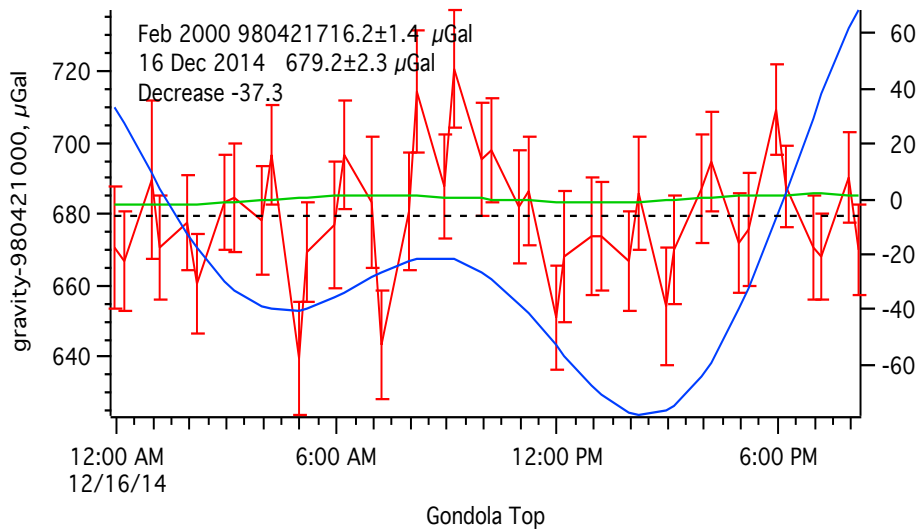
The mark now consists of a 2 cm diameter stainless -steel disk epoxied approximately flush with the concrete floor centered with a 3 cm long stainless steel screw. The point replaces a five pointed star glued to floor.



The new identifier mark on the floor near the base of a 55 gallon oil drum, and a view of the measurement location with Chris Pearson in the foreground.

3. Gondola Top station

-43.5894°S 172.7166E Elevation 445m Gradient -3.81 $\mu\text{Gal}/\text{cm}$
 2000 value at 1m was 980 421 716.2 \pm 1.4
 17 Dec 2014 value at 1m is 980 421 679.2 \pm 2.3
 23 Jan 2015 value at 1 m is 980 421 675.2 \pm 2.3
 Reduction in g is 418.0 μGal ie 10.97 cm uplift using free air gradient.
 17 December (Wednesday) started at 12:45 local
 December Height offset 15.0 cm, Vacuum start 0.40, spring near zero. Lower coarse bubble centered but lower precision bubbles were not centered.
 January all bubbles centered and spot-on. Low noise at night but high vibration and power line fluctuations.



The January measurement is 5 μGal lower than the Dec measurement. Possibly due to the tidal residual.

The point was previously identified by a five pointed star glued to floor . The floor was damaged in the 2010 earthquake and after regrouting cracks the floor was

ground smooth and painted leaving no trace of the mark. The mark now consists of a 2 cm diameter stainless steel disk epoxied approximately flush with the concrete floor centered with a 3 cm long stainless steel flat-head screw. A plaque originally located on the wall about 4 feet above the floor, had been removed during post earthquake painting, and was re-glued into position.



Absolute Gravity Gondola Top
980422071.0 μGal floor level
gradient 381 $\mu\text{Gal}/\text{m}$
9 Feb. 2000 FG5-111 NZF/CIRES
For more information contact LINZ



Mark Forster next to top Gondola measurement point showing reinstalled wall plaque. Newly recessed floor mark is below lower tripod. (gondola@welvomeaboard.co.nz) The freezer room is to the right of the door visible in the photo.

The point is to the south of the main freezer at the end of the corridor from the disembarkation point at the top of the Gondola. The corridor is prohibited from public access.

4. Botanical Gardens, Christchurch, Gravity up 53.0±5

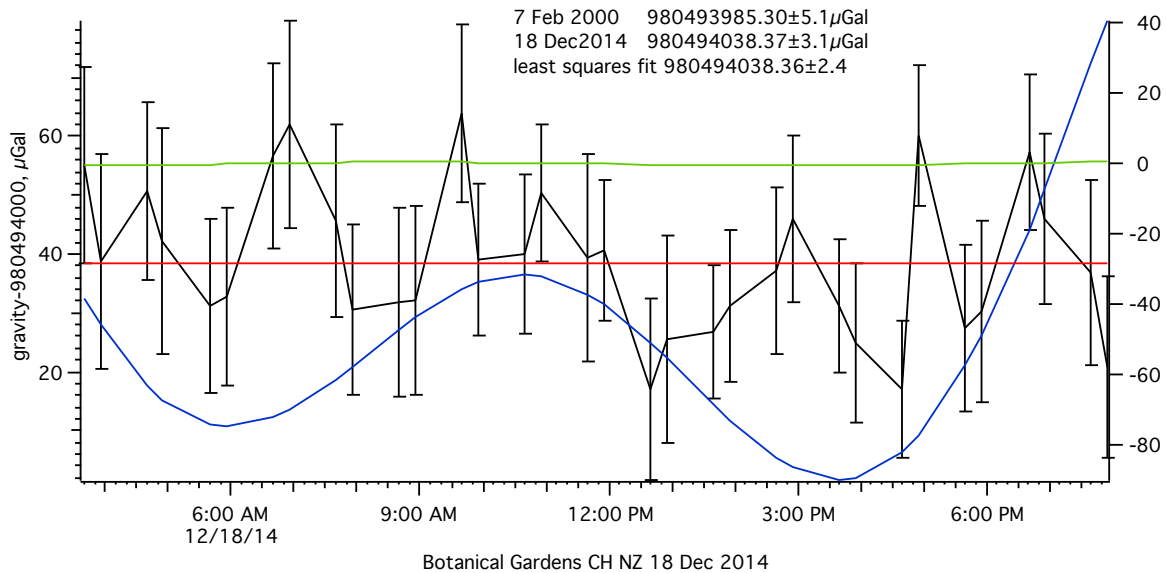
Botanical Gdns	Latitude	Longitude	Grad.	elevation	sets	RB	gradient	$\mu\text{Gal @ 1m}$	error
2000 value	-43.5293	172.6193	-3.60	7m			3.6	980493 985.3	5.1
18 Dec2014 (19f)					34	1.72		980494 038.37	3.6
19f	Weighted least squares fit							980494038.36	2.4



Sue Molloy at the Botanical Gardens, Christchurch. The inscribed value 980494 2(79) dated 6 Feb 2000 may have been a provisional number, since it is 293 μGal higher than the "0"m value calculated in Feb 2000 (980494 345.3) corresponding to a gravity point 81 cm below Feb 2000 ground level (67 cm below Dec 2014 ground level. View of

building (labeled workshop) shows met station in background. The magnetic observatory buildings (visited by Gutenberg and Richter in the 1960's) were originally in front of this workshop.





Notes The instrument would not give good residuals apparently because of superspring errors (various stops and starts are registered as data sets 19 Dec a,b,c, d and e during which the delay was increased from 25 ms to 35 ms and eventually 40 ms. After dismantling the superspring, a loose magnet was identified and removed that had prevented mechanical centering. Afterwards good data were acquired with a 40 ms delay, and the delay was reduced to 35 s and a new run started 19 Dec(e) at 4:30 pm. The vacuum DC power was inadvertently off for about an hour and by 4:30 it had dropped to $0.84 \cdot 10^{-4}$. By 5 PM the vacuum had fallen further but at a lower rate but by 5 :15 the vacuum was improving. During this time the ion pump voltage was steady at 4kV . The temperature in the room increased and required opening the door to cool it down from midday to 5 pm. Finally the fiber entry point into the laser was found very sensitive and unstable and needed constant vigilance. Its instability caused the peak to peak fringe amplitude to climb over 400 mV and to fall to zero. There was no easy way to clamp this permanently in an optimum mode. The deviation on early runs (a b c d) was inordinately large due to the superspring magnet problem. Good data were finally obtained overnight (19f) whose data are shown above (but note low red-blue separation).

19 Dec 2014 local (18 Dec UT)

Vacuum start 0.50 midday. The vacuum reduced throughout the day $0.79\text{-}0.41\text{e-}4$ at 4pm started at 12:45 local but data bad, remove magnet in superspring, 17 hour run started at 8:30 pm.

Lower height measurement to floor 7.55 cm
 Upper height measurement 7.95 cm
 Height entered 15.50 cm

Polar motion entered $x=0.0426$ $y=0.2728$. 350 ± 5 mV peak to peak

The mark consisted of a crude cross chiseled into the concrete floor of the former observatory workshop. A 3 mm hole was drilled into the center of the cross surrounded by a diamond drilled hole sufficient to recess a 3 mm thick stainless washer. The washer was centered with a Philips-screw and was epoxied in place.

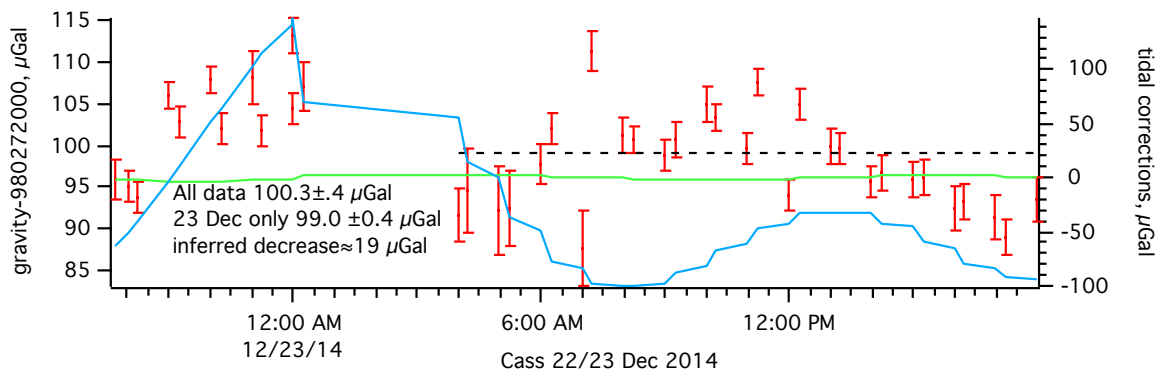
5. Cass, University of Christchurch field station Decrease $27.6 \pm 2 \mu\text{Gal}$
 -43.03500 Long: 171.75900 Elev: 610.00 m



Cass viewed from the west is 100 m north of the northerly clump of trees.



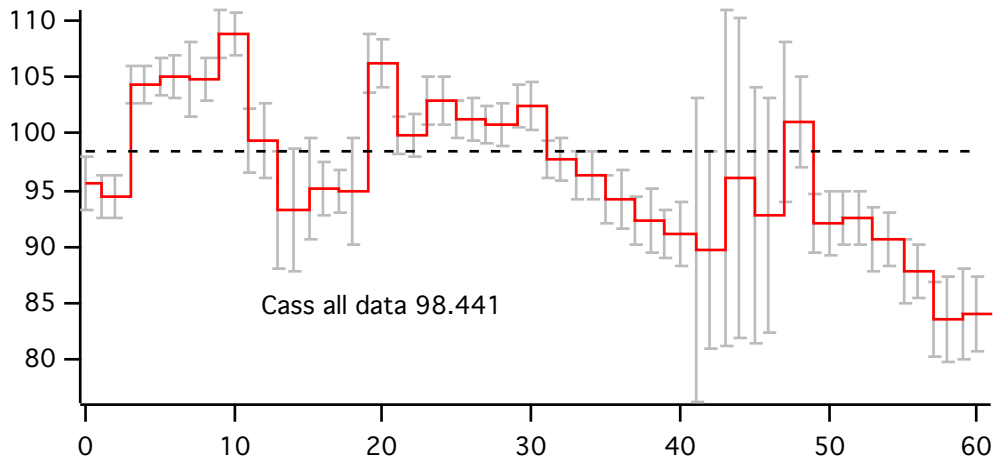
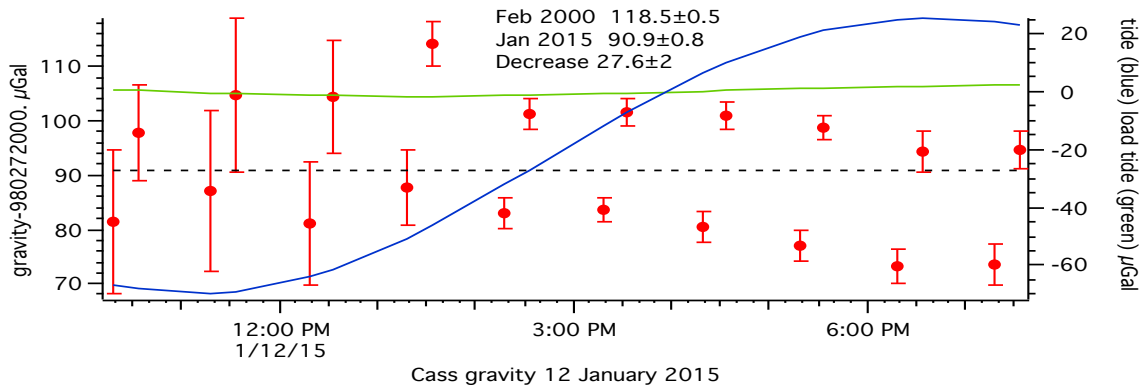
The instrument is set up above a Philips screw in the drying room. 36 hours of data were obtained in December and ten hours in January a week after a Mw=6 earthquake at a distance of 30 km. -43.06, 171.25 6.0 at 5 km (USGS 5.6 43.066°S 171.241°E depth=10.0 km) 2015-01-05 10:48:42 (UTC-07:00)



Notes: The ion pump was unable to hold the vacuum during the drive from Christchurch (2 hours) and the turbo pump was therefore installed and run overnight. Inadvertently the bleed valve on the pump was open and on opening the main valve, air had entered the chamber. The poor resulting vacuum was not noticed until the next day because the ion pump voltage indicated normal voltages (4kV) and the pressure indicated a suspiciously low $1.2\text{E-}4$ torr. It was necessary to pump down for the next 24 hours to recover the vacuum and a further three days before the ion pump could sustain the value. While awaiting the vacuum pump-

down the system was dismantled to fix the superspring. Fred Klopping at Micro-g had, in an internet message, advised replacement of the magnet in the superspring to return its behavior to stable operation. The superspring cover was removed and the damping magnet assembly unfastened and removed (held by two screws). During removal a second magnet fell off its glued position suggesting that the aluminum.chromium glue adhesion was not very secure (the superglue remained on the chromium plate to the neodymium magnet. Five-minute Araldite epoxy was used to reposition the magnets with the same polarity that they had previously been glued. Tape was needed to hold the magnets during glue setting to prevent attractive forces from moving them from their centered positions. Were a second magnet placed behind each inward facing magnet, and both placed in a milled depression, the resulting pair of magnets would not need glue

On 12 January the point was reoccupied overnight, with considerable care to align bubbles and spot position.



Cass all data Average 98.4 ± 0.3 Decrease 20.1 ± 2 μGal

6. Bealey Hotel 24 Dec

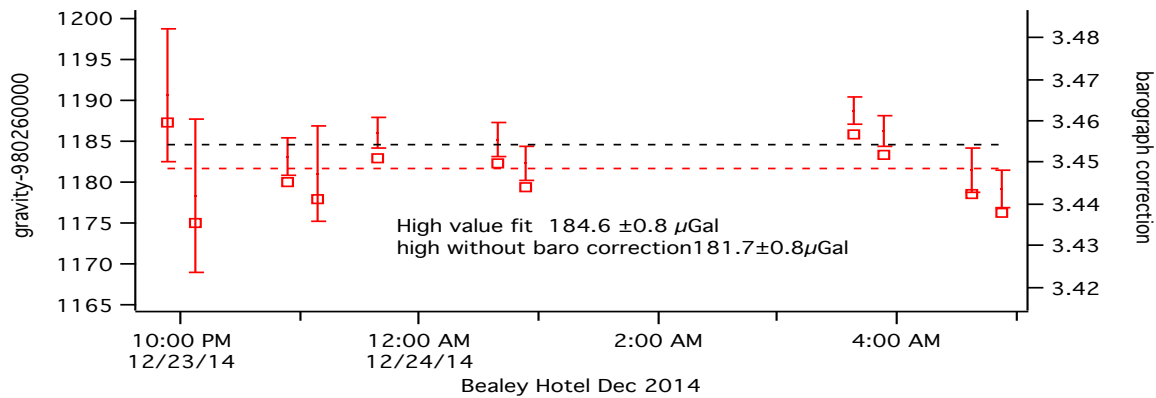
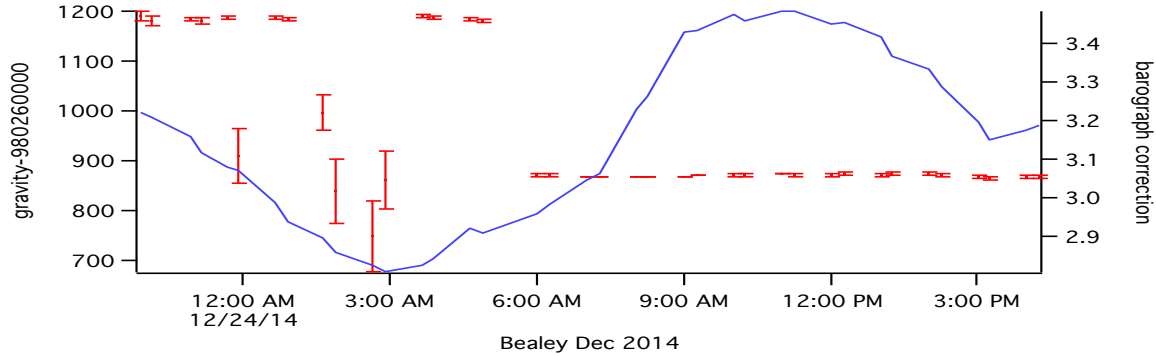
Feb 2000	-43.02	171.61	-2.73	629	sets r/b	187.8	0.5
24 Dec 2014				4	6.7	182.0	2.2
24B Dec2014	barograph operating +2.91			12	2.1	184.2	3.5
	<i>Least squares fit, outliers removed ,and no baro correction</i>					181.7	0.7
24C Dec 2014	discarded			23	0.06	870.6	2.1
12 Jan 2015	barograph not operating!			29	19	178.8	0.8
	<i>Least squares fit no barograph correction</i>			28		179.9	0.4



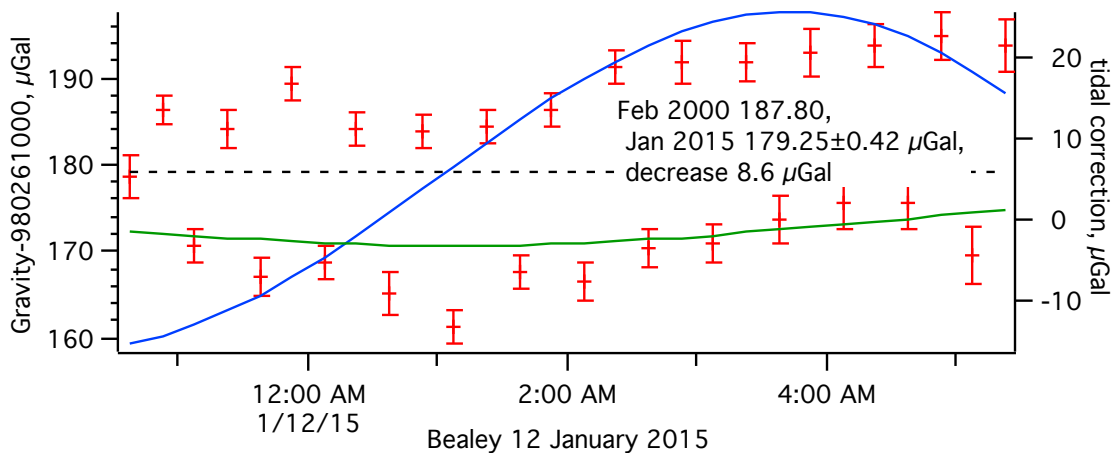
Point is in recess at back left of first garage door on left. All three data runs were recorded with the turbo pump connected because, due to the previous day's vacuum leak, the ion pump voltage fell rapidly in its absence. In the second sequence the hour was incorrectly set on the computer (hour and day both 23) but was adjusted +7 hours in subsequent processing. The third and longest run (overnight with low scatter), however, yielded a significantly lower value. Its value corresponds to a possible misalignment of the vertical by 0.045° but the blue red separation was also extraordinarily low (0.06). The top levels and the lower coarse level were correctly aligned but the lower precise bubble levels were not checked. The red blue relation appears inverted.

The elevations here are not precise, so identical values (629m and 939.93mb) were used in February 2000 and for the present data. The turbo-pump was operated for the December sessions due to a previous vacuum problem at Cass. The red blue separation was low for all these sessions with occasional low outliers. The 24C session with zero red/blue separation due to its low value was discarded (laser frequency not stable? The same unreasonably low value was obtained initially at the next site, Arthur's Pass). The lower precision-bubbles were not set, but the

coarse bubble was centered. Due to uncertainties in the early data, the site was re-occupied 12 January taking care to set lower and upper precision levels, however the barometer was at this time not working for this site (3.225 V at 22:34, 3.227 V at 1:30 and 3.214V at 7), and although the laser started flashing only after set-five, the blue/red separation was reasonable (19 μGal).



Bimodal values recorded at Bealey. The lower ones are clearly outliers because the higher values differ from the January values by only 4 μGal , and by 2 μGal if the barograph correction is omitted (lower plot). Red/blue pairs appear inverted?

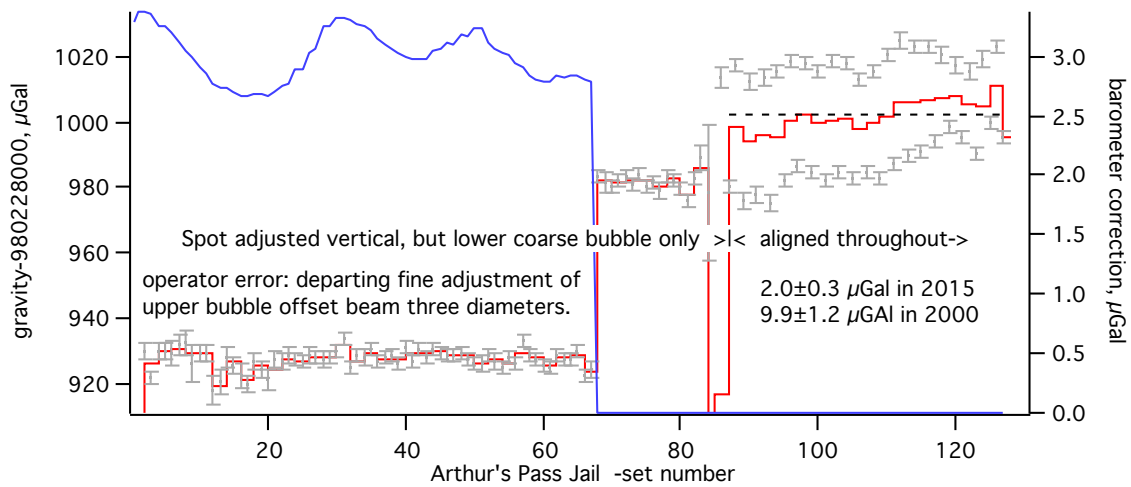


12 January 2015 data from Bealey. The missing barograph correction is +0.7 μGal initially +.9 μGal for set 6, and -0.7 μGal at the end (based on voltage measurements) so that its mean corrected value differs little from that indicated.

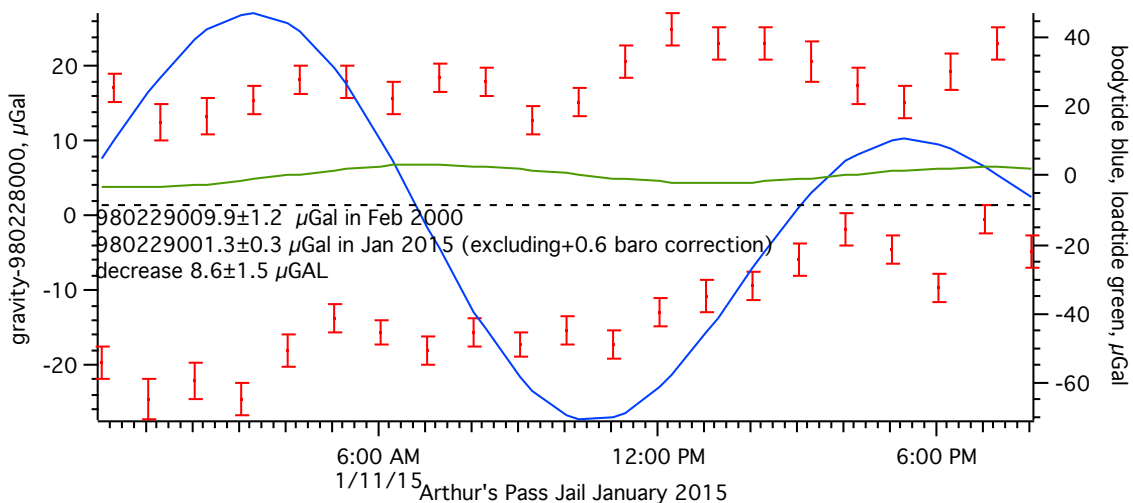
7. Arthurs Pass Jail Dec 2014-Jan 2015 -42.95 171.57 (elevation used 732.7 m)
 Decrease is $8.6 \pm 1.5 \mu\text{Gal}$

12 Jan Arthurs Pass 3 41 sets, $002.4 \pm 0.8 \mu\text{Gal}$, red/blue separation= $31.3 \mu\text{Gal}$

The jail is inside the police station, and the key was left for us at the Visitors center in Arthur's Pass. Two unacceptable data sets were acquired 24/25 Dec 2014, mired by accidental operator errors, but the measurements were repeated successfully 11 January 2015. The instrument was left running for 37 hours with the turbo pump 24-25 December due to doubts about the ion pump (repaired before next site). On return the instrument was diagnosed as having been leveled *after* spot alignment - its spot position was three diameters off and its data discarded. After re-leveling, the instrument was restarted running overnight only on the ion pump, but its lower precision bubbles were not aligned, only the coarse bubble. The data were good until about 5 am when the system refused to drop- a loose connection between the computer and the Magma A-D board. The January measurements use manual barometer observations.



Graph of all Arthur's Pass Jail acquisitions. Earlier values are unacceptable due to laser misalignment and superspring verticality problems. For the reliable data below (also shown above right) the observed slope must be corrected using manual barometer observations.



Manual Barometer Readings Arthurs Jail (nominal pressure entered 928.7 mbar)
 Conversion factor volts*125+537.5

date and time UT	volts	mb	Correction	
			mb	μGal
01/10/2015 23:11:00	3.146	930.75	2.48	0.744
01/10/2015 23:59:00	3.144	930.5	2.23	0.669
01/11/2015 01:26:00	3.141	930.125	1.855	0.5565
01/11/2015 03:00:00	3.146	930.75	2.48	0.744
01/11/2015 20:15:00	3.135	929.375	1.105	0.3315

Offset January measurements 14.7 cm, gradient -2.33 μGal/cm, vacuum 0.64×10^{-4} , Torr



A screw in the floor marks the precise position. When aligned north, the NW foot of the tripod lies above a crack in the concrete which renders tilt sensitive to the observer's position.

8. James Scott's Hanger, 10 km south of Fox Glacier

location	Latitude	Longitude	Grade	elevation	Feb2000 μ Gal	2014/15 μ Gal	change
Helipad	-43.534	169.839	2.92	70	980439547.4	980439547.8	1.3 $0.4\pm$

An ion pump problem was fixed at this site while waiting for clear weather. The turbo-pump was run continuously during repairs. The ion pump battery was found unable to maintain a vacuum for more than a few hours, and in the absence of a suitable external battery plug, it was dismantled and a cable extension inserted to by-pass the internal battery. The extension consists of a cable with female and male quick-disconnects that pass through the hole previously occupied by the 12V external socket. A 7.2AH 12 V gel-cell was taped to the outside. On reassembly no 4 kV voltage was detected, which further inspection revealed to be caused by a dry solder joint between the hi-tension cable and the feed through at the back of the case. Black soot deposits on the gold-plated turret beneath its heat-shrink shroud showed that arcing had occurred in the past, suggesting that this may have contributed to former vacuum problems. The joint was soldered and taped and voltages were found to be normal.

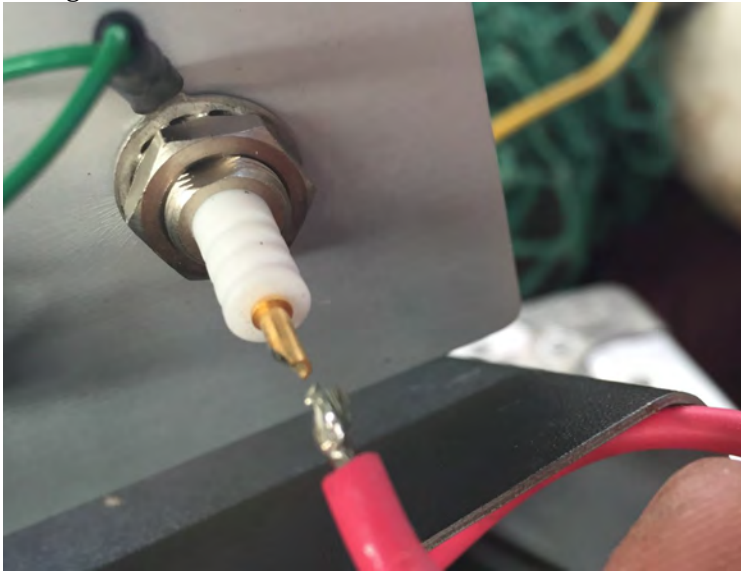
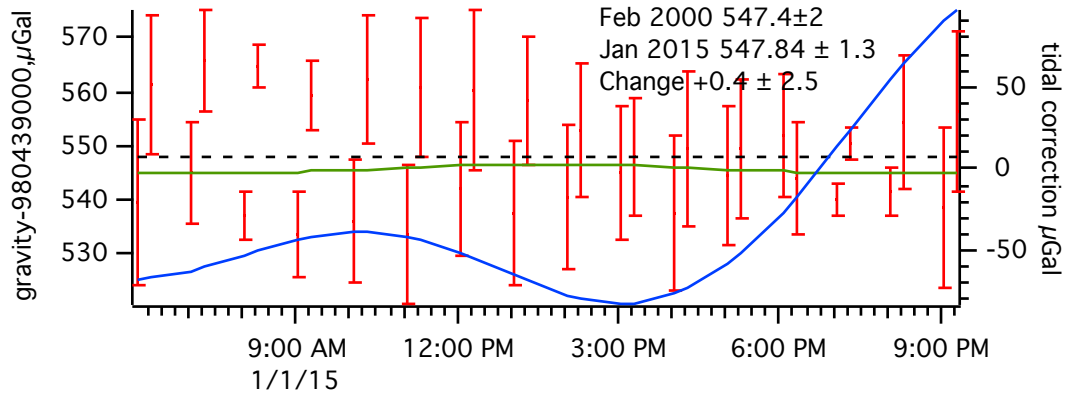


Photo shows absence of solder on the hi tension feed-through of the ion pump supply, prior to repair. Black arc deposits are faintly visible near cavity left of the gold-plated hole. Its heat shrink cover alone may have kept the joint in connected for some time.

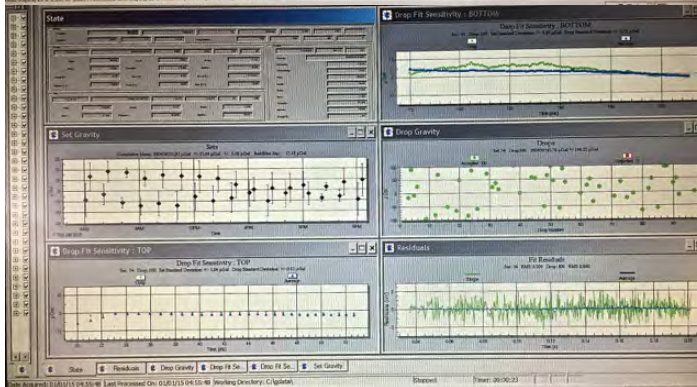
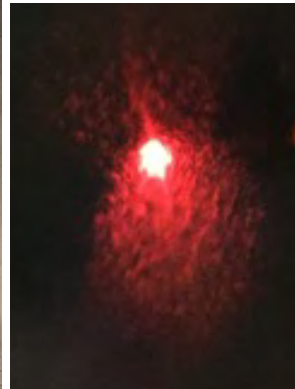
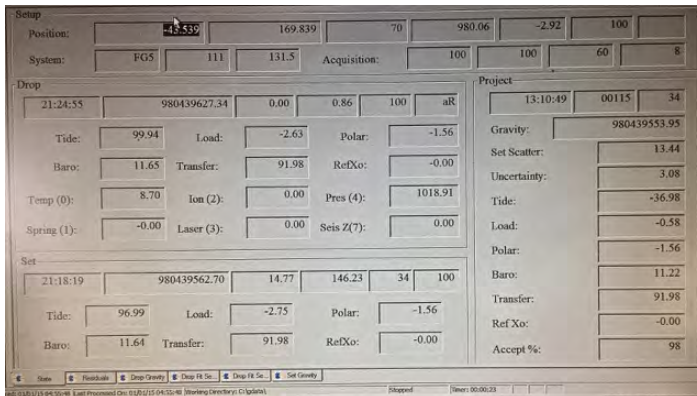
A review of procedures up to this point revealed that in all previous points alignment of the lower precision bubbles had been omitted. At this site and in all subsequent measurements and re-measurements, the instrument careful alignment of the lower and upper precision bubbles and the reflected spot position was undertaken in the stated order. The measurements were started at about 5 am on 1 January (6 pm local time) with vacuum $1.35E-4$, and spring $+2-4mV$. The fiber optic alignment from the laser initially gave almost zero light. Slight adjustment and tightening of the output fitting brought intensities to $>400mV$. Fringe amplitudes were adjusted to $350mV$ using the small fiber optic screw, and the resulting fringes displayed a remarkable absence of intensity variation during dropper carriage oscillation, presumably due to ultra precise alignment of lower bubbles. Photos of spirit levels were taken at this site and at subsequent sites for quality control.



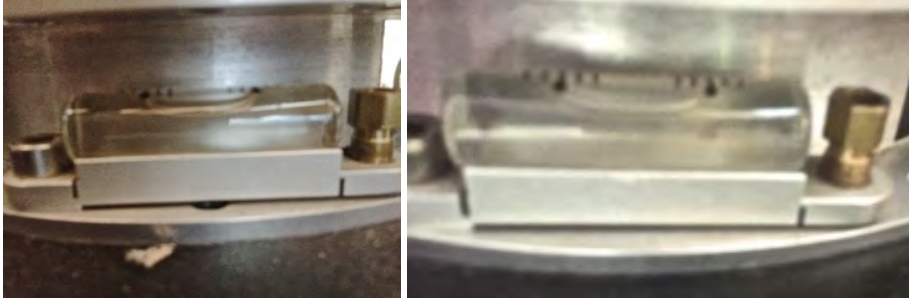
James Scotts Helicopter Hanger

Essentially no change at the helicopter hanger. 547.84 ± 1.3 compared to 547.4 ± 2 .

End of run Photos



top N and E bubbles at end of run 1 Jan 2015



bottom north and east bubble at end of run

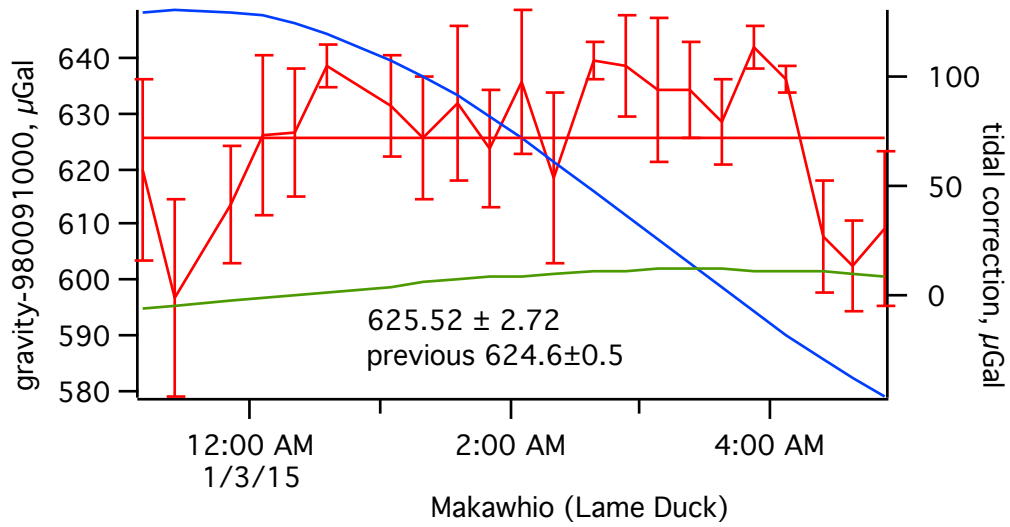
10. Lame Duck (Makawhio) 2 January

							sets	
L.Duck Feb 2000	-43.72	169.85	4.86	1630	980091624.6	0.6		
Lame duck January 2015					980091100.9		1	
Lame Duck 2245 1 January 2015					980091608.43	2.2	2	
Lame Duck 2345 1 January 2015					980091628.64	4.76	4	
Lame Duck 0057 2 January 2015					980091627.90	0.95	6	
Lame Duck0229 2 January 2015					980091639.13	2.36	2	
Weighted least squares fit					980091625.52	2.72	22	

The site took 15 minutes to fly to, 30 minutes to erect the gravity tent, 2 hours to level the tripod (the pad is not level) and 30 minutes to optimize the laser amplitude due to a combination of tripod/super-spring horizontal offset and fiber optic coupling. The system took 75 minutes to disassemble and place in the helicopter net, and 15 minutes to return to James' helicopter pad.



Five file sets of were obtained as a result of stopping the system to adjust beam overlap, fringe amplitude and bubble centering. The first set is rubbish, and the beam centering on the last three sets was 3 beam diameters off. Photographs were taken throughout of bubbles and beam overlap and these are time stamped in local time.



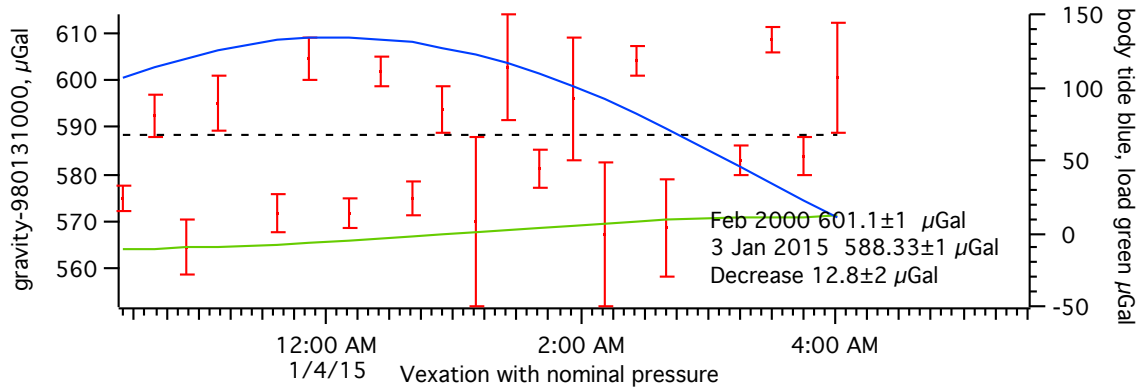
The new value is *higher* than the old value by 1 μGal but *within* the uncertainty. If one ignores the first 2 and last 3 points the new value is 5 μGal higher and 2 standard deviations. The only thing abnormal about the acquisitions was the laser which I do not recall seeing flashing at all.

11. Vexation -43.63767 169.89349E el 1478 m



Sessions measured are as follows:

Vexation	-43.637	169.893	4.4	1475	980131601.1	1.0	
Vexation January 2015					980131557.7	2.7	4
Vexation 11:28 3 January 2015					980131562.21	2.2	2
Vexation 12:02 3 January 2015					980131589.96	3.4	12
Vexation 15:10 3 January 2015					980131597.47	2.3	2
Least squares fit					980131588.33	0.9	20
decrease						12.8	±2

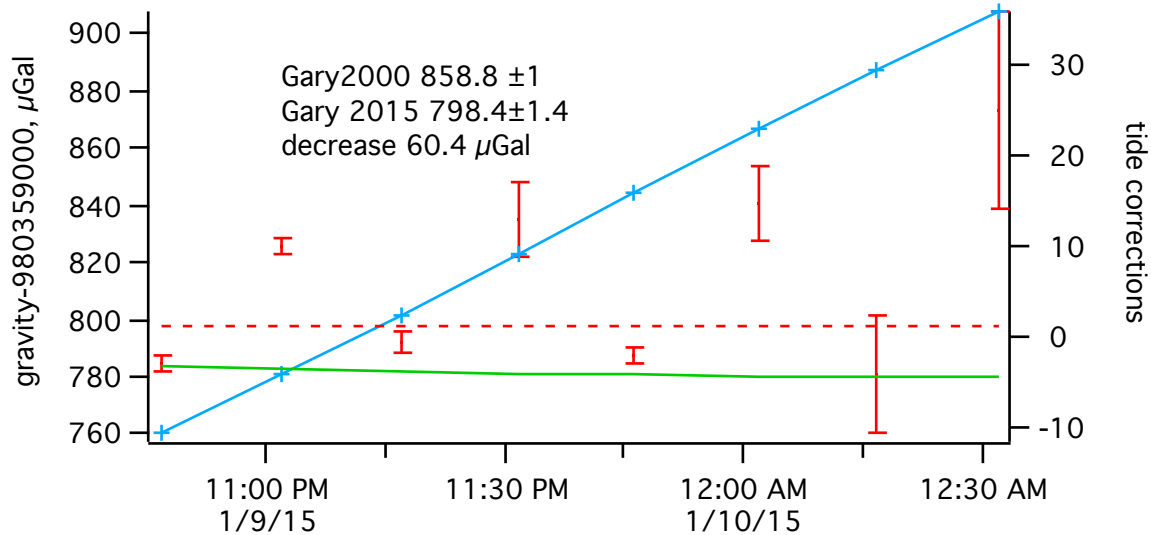


The concrete pads for the gravity measurements are not due north but there is of course no way to change this and the Coriolis correction will be the same for each occupation. The tent took 45 minutes to erect on solid rock using boulders. Two holes with pins were found in the rock from 15 years ago. The tent overhangs the flat part of the outcrop. As with Makawhio the pads are not level and this required considerable (2 hours) adjustment. The separation at the top between tripod and interferometer is about 1 cm more than usual, and because two legs of the tripod were fully extended the stability was poor. It was necessary to slide both tripod and base horizontally to align the beams correctly.

The large top separation was measured to be 8.57 ± 0.1 cm, the dip-stick base separation was 8.06 cm and the value entered was 16.62 for all measurements. The gradient was measured in 2000 to be $4.0 \mu\text{Gal}/\text{cm}$ – since this high value is critical to the transfer height comparison it might be of value to compare the gravity closer to actual heights measured, to be less sensitive to the gradient and small lateral and vertical offsets.

12. Gary's Rock 40 μGal decrease (groundwater draining from swamp?)

9 January data reprocessed with correct parameters 14 January



Gary's rock 9 January

9 January Gravity: **980359807.59** μGal

Set Scatter: 3.97 μGal

Lat: -42.64900 Long: 171.54000 Elev: 120.00 m

Actual Height: 132.80 cm

Gradient: -4.410 $\mu\text{Gal}/\text{cm}$
Nominal Air Pressure: 998.92 mBar
Setup Height: 16.50 cm

10 January data with the same input parameters.

10 Jan Gravity: **980359818.42** μGal
Set Scatter: 1.61 μGal
Lat: -42.64900 Long: 171.54000 Elev: 120.00 m
Setup Height: 16.50 cm
Transfer Height: 100.00 cm Actual Height: 132.80 cm
Gradient: -4.410 $\mu\text{Gal}/\text{cm}$
Nominal Air Pressure: 998.92 mBar
Polar Motion Coord: 0.0222 " 0.2865 "

Least squares fits

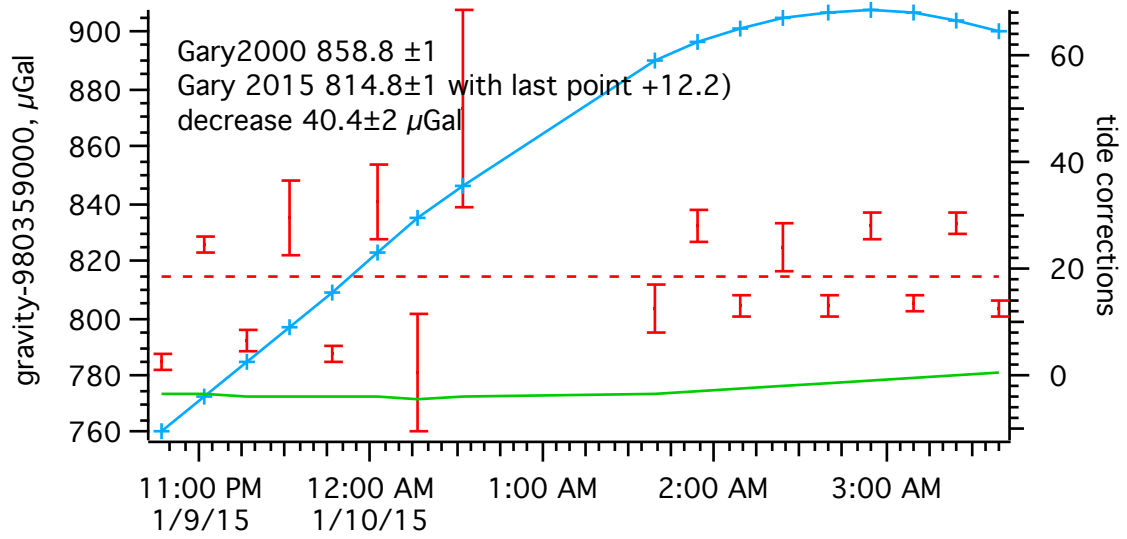
9 Jan only 805.9 \pm 1
g9 9 Jan 807.6 \pm 4
9 & 10 Jan 807.1 \pm 1 with last point +12.2 to compensate for missing red set
10 Jan only 814.81 \pm 1.4 ditto
g9 10 Jan 818.42 \pm 1.6

Adopted decrease is 858.8 - 818.4 = 40.4 μGal

No Barometer recorded

The valley is a water saturated bog that was drained many decades ago. The nearby stream and water-logged swales suggest that the region continues to be drained. A 40 μGal decrease would correspond to a >1 m decrease in water table in 15 years. After the 2010 Christchurch earthquakes the farmer opposite Gary's rock indicated that streams flowed during the dry season suggesting compaction during shaking. Mw=6.0 earthquake occurred earlier that day 100 km to the east.

The first set (9 Jan) was initially aligned well but data quality decayed and the last two points (not shown) were rejected as spurious due to poor fringe amplitude, a problem that developed in the last three points shown. It was decided to use only data from the second run (10 Jan) and to compensate the last data point (blue) by increasing it by (red+blue)/2=12.2 μGal . The resulting least squares value is 4 μGal below the output from g9 (818.4) which value was adopted for the 2015 value. The value in 2000 was 858.8 and hence the decrease is 40.4 \pm 2 μGal .



Gary's rock 9 /10 January 2015

combined data yields $46 \mu\text{Gal}$ decrease. Second set only yields $40\text{-}44 \mu\text{Gal}$ decrease.

13. Jacksons Garage decrease $6.9 \pm 1.5 \mu\text{Gal}$

The point is marked by a recessed stainless washer on the concrete floor in the garage of the owner at Jacksons Retreat, behind the office.



Feb 2000 50.9 ± 1

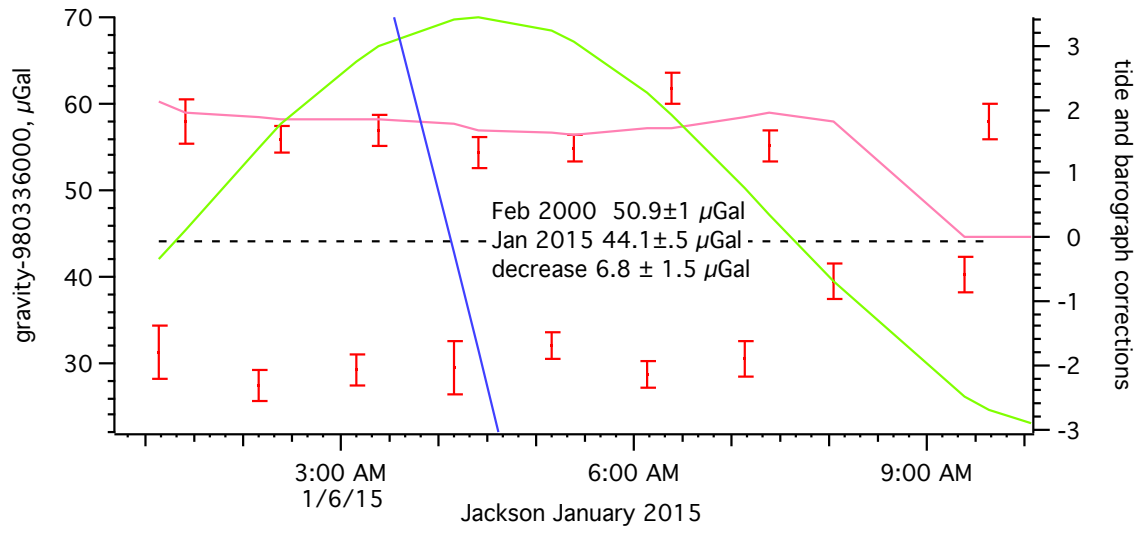
2245 5 Jan elevation 280 m 45.3 ± 2 14 sets

0745 6 Jan elevation 280m 39.57 1 set

0915 6 Jan elevation 280m 47.0 ± 9 optic fiber coupling problem- discard

igor $44.0 \pm 0.5 \mu\text{Gal}$ (point 14 $+12 \mu\text{Gal}$) 33 sets barometer working

decrease $6.9 \pm 1.5 \mu\text{Gal}$



Adopted data are shown.

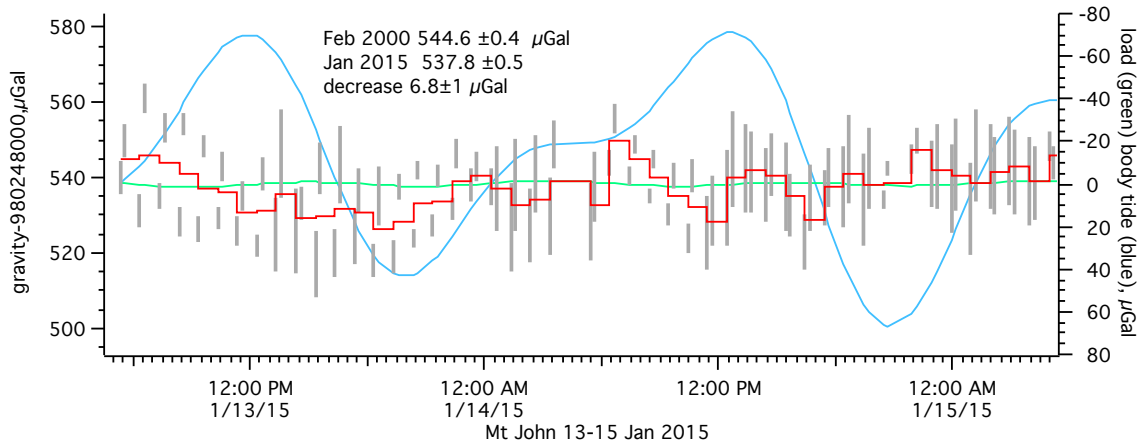
14. Mt John decrease $6.8 \pm 1 \mu\text{Gal}$

Access: drive to Lake Tepako from Christchurch (3 hours) and take the road to the Astro Café/Observatory about 1 km south of town. The Observatory at 102.5 m is open from 9-6. The measurement point is in the workshop building close to the west facing window wall and is marked by a 2 cm diameter circular hole. An Australian team planned to embed a more permanent mark when they measured the same point with an FG5 2 February 2015. It is not known whether they placed this new point coaxially with the one we measured.

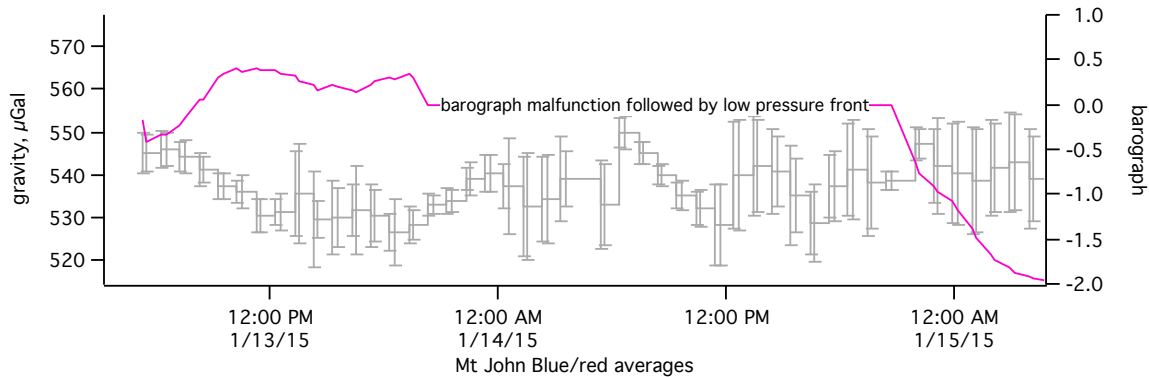


Operational notes: The instrument was set up 13 January with a combined mechanical offset of 14.65-14.7cm, vacuum $0.85\text{E-}4$ decreasing to $0.83\text{E-}4$ on 15 January, superspring ± 4 mV and bubbles and spot overlap checked twice each day. Power to the ion pump was inadvertently not connected and the vacuum became unacceptable early on the morning of the 15th (3.5 days from a 7.5 A gel cell) at the

same time as an inbound pressure low (700 mb) . The last 5 hours on the 15th of January were subsequently discarded.



Above: Two days of data from Mt John. The grey lines are the raw data and the red line the average of red/blue laser frequency pairs. Blue is body tide, green is load tide.

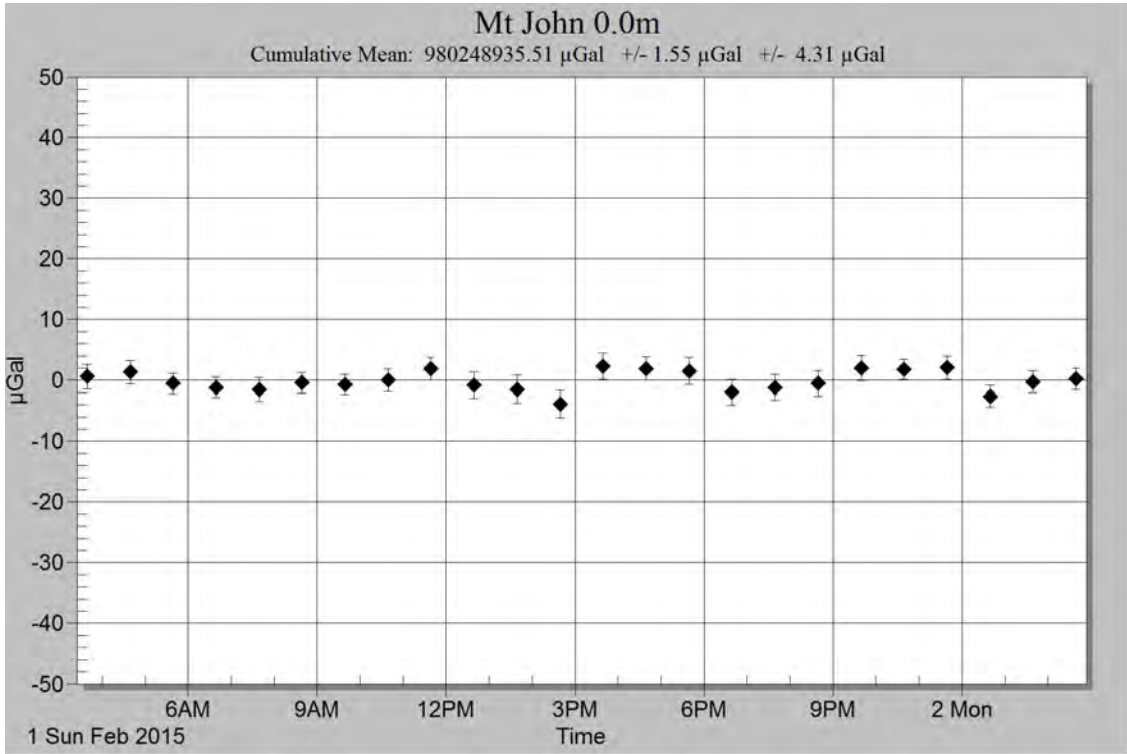


A successful attempt to repair the barometer was made at the start of the 15 Jan session after it failed midway through the 13 January session. Data after the vacuum failure are not shown.

Nick Dando from Australia and Vaughan Stagpoole occupied Mt John on 2 Feb 2015 with FG5-237 and measured a gradient of $-3.91 \mu\text{Gal}/\text{cm}$ with a value of $980248544.51 \pm 2 \mu\text{Gal}$ (Set Scatter: $1.55 \mu\text{Gal}$, Measurement Precision: $0.32 \mu\text{Gal}$, Total Uncertainty: $2.04 \mu\text{Gal}$ Number of Sets Collected: 24) Elevation 1032 m 896.26 mBar.

The elevation we used in 2000 and 2015 however was 1021.5 m (896.4 mBar). With an admittance factor of $0.3 \mu\text{Gal}/\text{m}$ the adjustment is negligible. We measured the same gradient $-3.913 \mu\text{Gal}/\text{cm}$ in 2000.

This value is higher than the value we measured in the previous month by $6.7 \mu\text{Gal}$. (and is coincidentally similar to the Feb. 2000 measurement value). It is not known whether their new measurement was at the same level and location as ours.



15. Leo Creek 20/21 January 2015 decrease -9.3 μGal .

-43.72067°S, 169.8522°N, Elevation 1274m: nominal pressure 869.27 mb
Measured offset 15.45 20 Jan. Time offset- computer was 4s in advance of GPS time.



The site was set up on the 20th initially in clear skies but heavy rain soon developed and the ion pump began to loose power due to a short in the ion pump cable. Measurements were abandoned and resumed the next day it was occupied in freezing conditions. The laser took an hour to stabilize (flashing) , but the superspring took more than 2 hours, presumably due to icing or heavy condensation inside the superspring chamber. The generator exhaust was

arranged to heat the spring chamber but it stabilized at -16 mV for the first six sets despite being driven to +20 mV manually. Initial fringe amplitudes could not be made to exceed 250mV due to condensation somewhere on the optics. After 3 hours the fringes climbed to 400 mV and were subsequently reduced to 350mV after which reliable data below were acquired. The bubbles and spot were checked after every four sets, sometimes more frequently but often no adjustments were needed. Maximum offset 1/2div. Despite the uniformity of operating conditions the noise level of some sets was undesirably large. Possibly cold air currents passing through the tent



