Absolute Gravity Observation at the National Measurement Institute

18th June 2008

Geoscience Australia
Record 2013/30

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Abbreviations

ANU Australian National University, Canberra, Australia

AuScope AuScope is a not for profit company funded by the National Collaborative Research Infrastructure Strategy capability 5.13 “Structure and evolution of the Australian continent”.

FG5 237 AuScope purchased, Micro-g Lacoste ballistic absolute gravimeter S/N 237.

GA Geoscience Australia, Canberra, Australia

NMI National Measurement Institute, Lindfield, Sydney, Australia.

RSES Research School of Earth Sciences, Australian National University

1 Gal = 1x10-2 m/s2

1 hPa = 100 Pa

# Introduction

An absolute gravity measurement was requested by National Measurement Institute (NMI) in the barometry laboratory (room C269) on the existing gravity bench mark “200498.9905”. Nicholas Dando from GA and Herb McQueen from RSES ANU performed the observation with FG5 237 over a 24hr period beginning 18th June 2008 00:56 UTC.

## Measurand

Mean free fall acceleration corrected for geophysical variations over the observation period to determine gravitational acceleration (in m/s2) at a reference height. The value of gravitational acceleration, g, includes the contribution of centrifugal force from the Earth’s rotation. For future reference and comparison purposes, the observed value was transferred vertically to a physical mark from a measurement height of 1.277m to 0.0m above the benchmark using a measured gravity gradient. An incorporated instrument device called the ‘superspring’ is used to mechanically isolate/filter the observations from ground accelerations e.g. micro-seismic noise and any other high frequency (greater than 1Hz) vibration sources in the floor. A small correction has been applied to estimate the instrument self attraction and laser beam diffraction of the FG5 model gravimeter, which alters the in-situ gravitational acceleration (Francis et al, 2012).

Geophysical corrections:

* Modelled Earth tides and ocean tide loading using the TPXO7.2 tidal model to produce a zero tide system (IERS conventions, 2010).
* An inverse barometer correction is applied to remove variations in local atmospheric density using an admittance factor of -3.0 x10-9 m/s2/hPa (Micro-g Lacoste , 2009)
* IERS Polar motion effects (variations of centrifugal force due to pole wandering) are estimated using IERS Bulletin A polar motion determinations (IERS conventions, 2010).

The corrections applied for Earth tides, ocean loading, inverse barometer and polar motion must be added back to the stated gravity value if it is intended to be used outside the stated observation period. Particularly for the Earth tides, as this effect can be over an order of magnitude larger than the stated uncertainty of the measurement if an instantaneous (less than a daily average) gravitational acceleration value is required, see Appendix B.

## Measurand Traceability

The FG5 ballistic absolute gravimeter uses physical standards of length and time realised through a Helium Iodine stabilised laser and a GPS constrained rubidium clock frequency to measure time distance pairs. Gravimeter operation procedures are confirmed via participation of the instrument and its operators in an organised intercomparison of absolute gravimeters. FG5 237 with operators Nicholas Dando and Ray Tracey participated in the European Comparison of Absolute Gravimeter’s (ECAG) 2011, (Francis et al, 2013).

## Measurand Uncertainty

The proprietary Micro-g Lacoste software, g8 (Micro-g Lacoste, 2009), calculates the gravitational acceleration value and uncertainty, however an expanded measurement uncertainty will be adopted from the unified FG5 model from the ECAG 2011 intercomparison (Francis et al, 2013). The expanded uncertainty associated with the measurement results is calculated in accordance with the principles in Guide to the expression of uncertainty in measurement (BIPM, 1995). A confidence interval of approximately 95%, a coverage factor k= 2 (BIPM, 1995), is used. A list of uncertainty components used for estimation of the expanded uncertainty is presented in Appendix C.

Long term local geophysical (type B) uncertainties outside the observation period are difficult to estimate without frequent gravity measurements. For the Lindfield NMI site an estimate of 5 µGal has been adopted. This site uncertainty estimate is from experience with other frequently measured sites around Australia and has potential contributions from:

* Foundation and structural movements.
* Groundwater variations consisting of soil moisture changes and/or water table movements.
* Mass changes near the measurement site. e.g. Earthworks, large volume fluid movements.

The other significant source of uncertainty (type A) with this measurement is the vertical gravity transfer down to the benchmark, using a measured gravity gradient. Typically repeat measurements are reported at the instrument measurement height, which minimises additional vertical transfer uncertainty. If the lowest possible uncertainty is required in another location in the laboratory other than above the benchmark, a gravity offset should be established with a relative gravimeter measurement.

## Methodology

An FG5 ballistic absolute gravimeter was used during the period to measure gravitational acceleration. The observation is performed by vertically dropping a test mass by a mechanical device in a vacuum chamber. A laser interferometer is used to determine the position of the test mass as a function of time during its freefall. More detail can be found in the FG5 Absolute Gravimeters User’s Manual, (Micro-g Lacoste, 2006). The measurement consists of an average of approximately 2400 test mass free-fall drops over a 24 hour period, typically comprising a set of 100 drops, with a set repeated every hour for 24 hours. Corrections are applied to every drop. A summary of these corrections applied to the sets are in Appendix A The instrument is set up and levelled over a survey benchmark to ensure the gravitational acceleration measurement can be spatially positioned with millimetre precision, relative to the benchmark.

## Site description

The measurement was performed over the benchmark installed in room C269 at the National Measurement Institute, Lindfield, Sydney inscribed “Absolute Gravity Station, 200498.9905, Sydney, Commonwealth of Australia”. This benchmark is in a suspended concrete floor within a larger masonry structure. Another attempted measurement on an older undocumented gravity mark in the same building failed as temporal tilting of the floor slab was significant enough to tilt the instrument out of a level alignment. This indicates that structural movements in the building could contribute to variations of the gravitational acceleration due to movements of the gravity benchmark relative to stable bedrock below the structure. This has been estimated in the expanded uncertainty for this site, Appendix C.

# Results

The calculated value of gravitational acceleration transferred down to the ground mark was measured to be 9796377953 x10-9 m/s2 +/- 106 x10-9 m/s2, with a confidence interval of approximately 95%. This is the gravitational acceleration value from the g8 software (see Appendix A), with the expanded uncertainty and corrections from ECAG 2011, (Francis et al, 2012, Francis et al, 2013), see Appendix C. Table 1 shows contribution to the gravitational acceleration value and uncertainties at the benchmark. A previous gravitational acceleration gradient measurement of -3.152 x10-6 m/s2 /m, from 2004, was used to transfer the gravity values down to the observation mark.

Table 1. Summary of the gravitational acceleration at the benchmark 200498.9905, over the observation period during the 18th June 2008, with expanded uncertainty and corrections.

| Contribution Source | Gravitational acceleration | Uncertainty (k=2) |
| --- | --- | --- |
| Gravitational acceleration (Appendix A) | 9796377945.1 x10-9 m/s2 |  |
| Expanded uncertainty (Appendix C) |  | 106 x10-9 m/s2 |
| Self attraction & laser beam effects correction (Appendix C) | +8.20 x10-9 m/s2 |  |
| Total gravitational acceleration | 9796377953.3 x10-9 m/s2 | 106 x10-9 m/s2 |

# References

Francis, O. et al, 2012. Final report of the regional key comparison EURAMET.M.G-K1: European Comparison of Absolute Gravimeters ECAG-2011. Metrologia, 49, 1-14.

Francis, O. et al, 2013. The European Comparison of Absolute Gravimeters 2011 (ECAG-2011) in Walferdange, Luxembourg: results and recommendations. Metrologia, 50, 1-12.

Guide to the Expression of Uncertainty in Measurement, BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, International Organization for Standardization, Printed in Switzerland, ISBN 92-67-10188-9, First Edition, 1993. Corrected and reprinted, 1995.

IERS Technical Note No. 36. IERS Conventions 2010, International Earth Rotation and Reference Systems Service (IERS). <http://www.iers.org/TN36/>

Micro-g Lacoste, 2006. FG5 Absolute Gravimeters User’s Manual. <www.microglacoste.com>

Micro-g Lacoste, 2009, g8 User’s Manual. [www.microglacoste.com](file:///%5C%5Cnas%5CGEMD%5Cgeodesy%5CGRAVITY%5CABSOLUTE_GRAVITY%5CFG5%20Measurement%20reports%5CNMI_2008%5Cwww.microglacoste.com)

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Results file of calculation via g8 processing software: g8 User’s Manual, (Micro-g Lacoste, 2009)

Micro-g Solutions g Processing Report

File Created: 21st Feb 2013, 14:39:17

Project Name: NMI-080617

g Acquisition Version: 3.102100

g Processing Version: 8.090227

Company/Institution:

Operator: Nick Dando, Herb McQueen

Station Data

Name: NMI Lindfield

Site Code: 200498.9905

Lat: -33.78180 Long: 151.15120 Elev: 62.77 m

Setup Height: 11.95 cm

Transfer Height: 0.00 cm

Actual Height: 127.73 cm

Gradient: -3.152 µGal/cm

Nominal Air Pressure: 1005.73 mBar

Barometric Admittance Factor: 0.30

Polar Motion Coord: 0.1724 " 0.5206 "

Earth Tide (ETGTAB) Selected

Potential Filename: C:\Program Files\Micro-g Solutions Inc\gWavefiles\ETCPOT.dat

Delta Factor Filename: C:\gData\AuScope 2006-2011\WD\_Bodytide.dff

Delta Factors

 Start Stop Amplitude Phase Term

 0.000000 0.000001 1.000000 0.0000 DC

 0.000002 0.249951 1.160000 0.0000 Long

 0.721500 0.906315 1.154250 0.0000 Q1

 0.921941 0.974188 1.154240 0.0000 O1

 0.989049 0.998028 1.149150 0.0000 P1

 0.999853 1.216397 1.134890 0.0000 K1

 1.719381 1.906462 1.161720 0.0000 N2

 1.923766 1.976926 1.161720 0.0000 M2

 1.991787 2.002885 1.161720 0.0000 S2

 2.003032 2.182843 1.161720 0.0000 K2

 2.753244 3.081254 1.07338 0.0000 M3

 3.791964 3.937897 1.03900 0.0000 M4

Ocean Load ON, Filename: C:\gData\NMI\_2008\_repro\g8\_TPXO72\_NMI-OceanLoad.olf

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

Amplitude (µGal): 3.985 0.829 1.075 0.727 0.888 0.324 0.247 0.202 0.062 0.029 0.000

Phase (deg): -63.8 -80.2 58.0 116.3 -52.8 67.1 -73.2 145.9 4.3 32.1 0.0

Instrument Data

Meter Type: FG5

Meter S/N: 237

Factory Height: 115.78 cm

Rubidium Frequency: 10000000.00000 Hz

Laser: WEO100 (229)

ID: 632.99117754 nm ( 0.97 V)

IE: 632.99119473 nm ( 0.50 V)

IF: 632.99121259 nm ( 0.09 V)

IG: 632.99123023 nm ( -0.32 V)

IH: 632.99136890 nm ( 0.00 V)

II: 632.99139822 nm ( 0.00 V)

IJ: 632.99142704 nm ( 0.00 V)

Modulation Frequency: 8333.340 Hz

Processing Results

Date: 06/18/08

Time: 12:26:08

DOY: 170

Year: 2008

Time Offset (D h:m:s): 0 0:0:0

Gravity: 979637794.51 µGal

Set Scatter: 1.09 µGal

Measurement Precision: 0.22 µGal

Total Uncertainty: 4.25 µGal

Number of Sets Collected: 24

Number of Sets Processed: 24

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

Number of Sets NOT Processed: 0

Set #s NOT Processed:

Number of Drops/Set: 100

Total Drops Accepted: 2381

Total Drops Rejected: 19

Total Fringes Acquired: 700

Fringe Start: 19

Processed Fringes: 601

GuideCard Multiplex: 4

GuideCard Scale Factor: 250

Acquisition Settings

Set Interval: 60 min

Drop Interval: 10 sec

Number of Sets: 24

Number of Drops: 100

Gravity Corrections

Earth Tide (ETGTAB): 2.27 µGal

Ocean Load: -0.06 µGal

Polar Motion: -7.12 µGal

Barometric Pressure: 1.47 µGal

Transfer Height: 402.60 µGal

Reference Xo: -0.00 µGal

Uncertainties

Sigma Reject: 3.00

Earth Tide Factor: 0.001

Average Earth Tide Uncertainty: 0.00 µGal

Ocean Load Factor: 0.10

Average Ocean Load Uncertainty: 0.01 µGal

Barometric: 1.00 µGal

Polar Motion: 0.05 µGal

Laser: 0.01 µGal

Clock: 0.50 µGal

System Type: 1.00 µGal

Tidal Swell: 0.00 µGal

Water Table: 0.00 µGal

Unmodeled: 0.00 µGal

System Setup: 1.00 µGal

Gradient: 3.832 µGal (0.030 µGal/cm)

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Table 2: Summary of NMI-20080617.set.txt file from the Micro-G Lacoste g8 software program, containing a breakdown of set statistics and corrections.

| Set | Time UTC  | DOY | Year | Gravity µGal | Sigma (1σ) µGal  | Error (1σ) µGal | Uncertainty (1σ) µGal | Tide corr.µGal | Ocean Load corr. µGal | Baro corr. µGal | FG5 Temp deg C | Baro. Pres. hPa | Accept |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | 0:56:09 | 170 | 2008 | 979637797.74 | 9.519 | 0.957 | 4.343 | -20.489 | 1.099 | 3.031 | 29.066 | 1015.833 | 99 |
| 2 | 1:56:00 | 170 | 2008 | 979637796.12 | 10.381 | 1.043 | 4.368 | -18.542 | 2.407 | 2.633 | 31.066 | 1014.508 | 99 |
| 3 | 2:56:06 | 170 | 2008 | 979637794.93 | 10.951 | 1.095 | 4.386 | -28.124 | 3.160 | 2.456 | 31.265 | 1013.916 | 100 |
| 4 | 3:56:06 | 170 | 2008 | 979637793.97 | 12.174 | 1.217 | 4.418 | -45.945 | 3.075 | 1.720 | 31.177 | 1011.464 | 100 |
| 5 | 4:56:06 | 170 | 2008 | 979637794.79 | 9.310 | 0.940 | 4.344 | -65.612 | 2.093 | 1.614 | 31.184 | 1011.111 | 98 |
| 6 | 5:56:10 | 170 | 2008 | 979637794.02 | 10.122 | 1.017 | 4.356 | -79.316 | 0.385 | 1.619 | 31.206 | 1011.126 | 99 |
| 7 | 6:56:06 | 170 | 2008 | 979637794.96 | 12.888 | 1.289 | 4.431 | -79.912 | -1.670 | 1.505 | 31.424 | 1010.746 | 100 |
| 8 | 7:56:09 | 170 | 2008 | 979637794.39 | 9.280 | 0.933 | 4.352 | -63.064 | -3.604 | 1.546 | 31.306 | 1010.884 | 99 |
| 9 | 8:56:09 | 170 | 2008 | 979637794.90 | 7.921 | 0.800 | 4.338 | -28.634 | -4.947 | 2.121 | 31.277 | 1012.800 | 98 |
| 10 | 9:56:06 | 170 | 2008 | 979637793.59 | 9.764 | 0.976 | 4.379 | 18.880 | -5.368 | 2.147 | 31.271 | 1012.888 | 100 |
| 11 | 10:56:17 | 170 | 2008 | 979637794.94 | 9.675 | 0.982 | 4.374 | 71.497 | -4.742 | 1.188 | 31.329 | 1009.690 | 97 |
| 12 | 11:56:12 | 170 | 2008 | 979637794.56 | 9.229 | 0.932 | 4.35 | 118.552 | -3.205 | 1.727 | 31.305 | 1011.485 | 98 |
| 13 | 12:56:06 | 170 | 2008 | 979637793.28 | 10.087 | 1.009 | 4.358 | 150.604 | -1.097 | 1.466 | 31.301 | 1010.618 | 100 |
| 14 | 13:56:06 | 170 | 2008 | 979637794.67 | 9.397 | 0.940 | 4.342 | 160.855 | 1.112 | 1.222 | 31.299 | 1009.804 | 100 |
| 15 | 14:56:09 | 170 | 2008 | 979637793.25 | 9.579 | 0.963 | 4.355 | 146.987 | 2.930 | 0.997 | 31.302 | 1009.052 | 99 |
| 16 | 15:56:10 | 170 | 2008 | 979637795.08 | 11.067 | 1.112 | 4.398 | 111.977 | 3.971 | 1.029 | 31.278 | 1009.160 | 99 |
| 17 | 16:56:08 | 170 | 2008 | 979637794.07 | 9.462 | 0.951 | 4.36 | 63.259 | 4.052 | 0.846 | 31.249 | 1008.549 | 99 |
| 18 | 17:56:06 | 170 | 2008 | 979637795.05 | 11.867 | 1.187 | 4.41 | 10.763 | 3.231 | 0.853 | 31.307 | 1008.572 | 100 |
| 19 | 18:56:11 | 170 | 2008 | 979637792.57 | 10.197 | 1.025 | 4.361 | -35.504 | 1.784 | 0.741 | 31.257 | 1008.200 | 99 |
| 20 | 19:56:06 | 170 | 2008 | 979637793.26 | 11.179 | 1.118 | 4.381 | -67.526 | 0.142 | 0.812 | 31.234 | 1008.436 | 100 |
| 21 | 20:56:06 | 170 | 2008 | 979637792.78 | 11.387 | 1.139 | 4.388 | -81.629 | -1.244 | 0.884 | 31.289 | 1008.675 | 100 |
| 22 | 21:56:06 | 170 | 2008 | 979637794.56 | 11.231 | 1.123 | 4.387 | -78.551 | -1.998 | 0.861 | 31.292 | 1008.599 | 100 |
| 23 | 22:56:06 | 170 | 2008 | 979637795.02 | 10.446 | 1.045 | 4.367 | -63.166 | -1.935 | 1.443 | 31.308 | 1010.540 | 100 |
| 24 | 23:56:10 | 170 | 2008 | 979637795.22 | 10.042 | 1.014 | 4.356 | -42.860 | -1.095 | 0.890 | 31.277 | 1008.698 | 98 |

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Table 3: Unified FG5 model, instrumental uncertainty for FG5 237

| Influence parameters, xi | Value | Unit | ui or ai | Type A, i | Type B, ai | Corr. g | Type of dist. | Equiv. variance | Sens. coeff. | Cont. to the variance | Deg. of freedom i | Equiv. stand. Uncert. | ui4(y)/i |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Laser frequency |  | Hz | 1.0E-01 | 1.0E-01 |  |  | gaussian | 1.0E-02 | 2.1E-08 | 4.4E-18 | 30 | 2.1E-09 | 6.5E-37 |
| Laser frequency reproducibility |  | Hz | 1.0E-02 | 1.0E-02 |  |  | gaussian | 1.0E-04 | 2.1E-08 | 4.4E-20 | 30 | 2.1E-10 | 6.5E-41 |
| Rb-clock frequency |  | Hz | 5.0E-04 | 5.0E-04 |  |  | gaussian | 2.5E-07 | 2.0E-06 | 1.0E-18 | 30 | 1.0E-09 | 3.3E-38 |
| Gravity gradient measurement |  | m·s-2·m-1 | 5.0E-12 | 5.0E-12 |  |  | gaussian | 2.5E-23 | 8.3E+02 | 1.7E-17 | 15 | 4.2E-09 | 2.0E-35 |
| Misalignments in the verticality of the laser beam correction | 6.60E-09 | m·s-2 | ±2,1E-09 |  | 2.1E-09 | 6.6E-09 | rectangular | 1.5E-18 | 1 | 1.5E-18 | 15 | 1.2E-09 | 1.4E-37 |
| Imperfect collimation and cosine error effect |  | m·s-2 | 1.0E-09 | 1.0E-09 |  |  | gaussian | 1.0E-18 | 1 | 1.0E-18 | 15 | 1.0E-09 | 6.7E-38 |
| Verticality |  | Rad | 4.8E-05 |  | 4.8E-05 |  | rectangular | 7.7E-10 | 1.41E-04 | 1.5E-17 | 15 | 3.9E-09 | 1.6E-35 |
| Residual gas pressure | 2.0E-04 | Pa | ±2E-04 |  | 2E-04 | 3.6E-09 | rectangular | 1.3E-08 | 1.8E-05 | 4.3E-18 | 5 | 2.1E-09 | 3.7E-36 |
| Beam shear effect | unknown |  | unknown |  |  |  |  | 0.0E+00 |  | 0.0E+00 |  | 0.0E+00 | 0.0E+00 |
| Glass wedges |  | Rad |  | 2.9E-05 |  |  | gaussian | 8.4E-10 | -1.4E-04 | 1.6E-17 | 15 | 4.1E-09 | 1.8E-35 |
| Corner cube rotation |  | rad·s-1 | ±1E-02 |  | 1E-02 |  | rectangular | 3.3E-05 | 6.0E-07 | 1.2E-17 | 15 | 3.5E-09 | 9.6E-36 |
| Air gap modulation |  | Mm | 1.5E-07 | 1.5E-07 |  |  | gaussian | 2.3E-14 | 4.9E-02 | 5.4E-17 | 15 | 7.4E-09 | 1.9E-34 |
| Inhomogeneous magnetic field |  | T | ±5E-05 |  | 5E-05 |  | rectangular | 8.3E-10 | 7.0E-05 | 4.1E-18 | 15 | 2.0E-09 | 1.1E-36 |
| Electrostatics effect |  | m·s-2 | 1.0E-09 | 1.0E-09 |  |  | gaussian | 1.0E-18 | 1 | 1.0E-18 | 15 | 1.0E-09 | 6.7E-38 |
| Temperature changes |  | °C | ±4E+00 |  | 4E+00 |  | U | 8.0E+00 | 7.0E-10 | 3.9E-18 | 10 | 2.0E-09 | 1.5E-36 |
| Self attraction | 5.00E-09 | m·s-2 | 5.00E-09 | 5.00E-09 |  | -1.40E-08 | gaussian | 2.5E-17 | 1 | 2.5E-17 | 30 | 5.0E-09 | 2.1E-35 |
| Diffraction effects (correction) | 5.00E-09 | m·s-2 | 5.00E-09 | 5.00E-09 |  | 1.20E-08 | gaussian | 2.5E-17 | 1 | 2.5E-17 | 10 | 5.0E-09 | 6.3E-35 |
| Index of refraction effect |  |  | negligible |  |  |  |  | 0.0E+00 |  | 0.0E+00 |  | 0.0E+00 | 0.0E+00 |
| Phase shifts in fringe counting and timing electronics |  | S | ±1E-08 |  | 1E-08 |  | rectangular | 3.3E-17 | 5.2E-01 | 9.0E-18 | 15 | 3.0E-09 | 5.4E-36 |
| Photodetection and fringe counting electronics effect |  |  | negligible |  |  |  |  | 0.0E+00 |  | 0.0E+00 |  | 0.0E+00 | 0.0E+00 |
| Finite speed of light effect |  |  | negligible |  |  |  |  | 0.0E+00 |  | 0.0E+00 |  | 0.0E+00 | 0.0E+00 |
| Choice of the initial and final scaled fringes effect |  | m·s-2 | 1.3E-08 | 1.3E-08 |  |  | gaussian | 1.7E-16 | 1 | 1.7E-16 | 15 | 1.3E-08 | 1.9E-33 |
| Optical effects |  |  | negligible |  |  |  |  | 0.0E+00 |  | 0.0E+00 |  | 0.0E+00 | 0.0E+00 |
| Reference height |  | m | ±1E-03 |  | 1E-03 |  | rectangular | 3.3E-07 | 3.0E-06 | 3.0E-18 | 30 | 1.7E-09 | 3.0E-37 |
| Radiation Pressure effect |  |  | negligible |  |  |  |  | 0.0E+00 |  | 0.0E+00 |  | 0.0E+00 | 0.0E+00 |
| Others |  |  | negligible |  |  |  |  | 0.0E+00 |  | 0.0E+00 |  | 0.0E+00 | 0.0E+00 |
| Total correction | 8.20E-09 | m·s-2 | Sum of variances | 3.67E-16 | m2·s-4 |  | 2E-33 |
| Combined standard uncertainty, u | 1.9E-08 | m·s-2 |  |  |
| Degrees of freedom, eff (Welch-Satterthwaite formula) | 59 |  |  |  |
| Confidence level, p | 95% |  |  |  |
| Coverage factor, k (calculated with t-Student) | 2.00 |  |  |  |
| Expanded uncertainty (corrections applied), U = ku | 3.8E-08 | m·s-2 |  |  |
| Relative expanded uncertainty (corrections applied), Urel = U/g | 3.9E-09 |  |  |  |

Table 4: Unified FG5 model, Lindfield NMI site dependent uncertainty

| Influence parameters, xi | Value | Unit | ui or ai | Type A, i | Type B, ai | Type of distribution | Equivalent variance | Sensitivity coefficients | Contribution to the variance | Deg. of freedom, i | Equiv. stand. Uncert. | ui4(y)/i |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Air pressure measurement effect |  | m·s-2 | ±1.00E-09 |  | 1.0E-09 | rectangular | 3.3E-19 | 1.0E+00 | 3.3E-19 | 30 | 5.8E-10 | 3.7E-39 |
| Earth tide evaluation. \*from g8\* |  | m·s-2 | 2.27E-11 |  | 2.3E-11 | rectangular | 1.7E-22 | 1.0E+00 | 1.7E-22 | 30 | 1.3E-11 | 9.8E-46 |
| Ocean loading correction evaluation. \*from g8\* |  | m·s-2 | 6.00E-11 |  | 6.0E-11 | rectangular | 1.2E-21 | 1.0E+00 | 1.2E-21 | 30 | 3.5E-11 | 4.8E-44 |
| Polar motion correction evaluation |  | m·s-2 | ±0,5E-11 |  | 5.0E-10 | rectangular | 8.3E-20 | 1.0E+00 | 8.3E-20 | 30 | 2.9E-10 | 2.3E-40 |
| Coriolis acceleration effect |  | m·s-2 | ±7,5E-09 |  | 7.5E-09 | rectangular | 1.9E-17 | 1.0E+00 | 1.9E-17 | 15 | 4.3E-09 | 2.3E-35 |
| Floor (instrument) recoil effect |  | m·s-2 | ±2E-09 |  | 2.0E-09 | rectangular | 1.3E-18 | 1.0E+00 | 1.3E-18 | 15 | 1.2E-09 | 1.2E-37 |
| Gravity gradient (1.277m to 0.0 m) \*from g8\* |  | m·s-2 | 3.83E-08 | 3.8E-08 |  | gaussian | 1.5E-15 | 1.0E+00 | 1.5E-15 | 30 | 3.8E-08 | 7.2E-32 |
| Standard deviation of measurements. \*from g8\* |  | m·s-2 | 1.09E-08 | 1.1E-08 |  | gaussian | 1.2E-16 | 1.0E+00 | 1.2E-16 | 30 | 1.1E-08 | 4.7E-34 |
| Water Table, foundation movement. \*NMI site estimate\* |  | m·s-2 | 5.00E-08 |  | 5.0E-08 | rectangular | 8.3E-16 | 1.0E+00 | 8.3E-16 | 30 | 2.9E-08 | 2.3E-32 |
| Sum of variances | 2.84E-15 | m2·s-4 |   | 9.8E-32 |
| Combined standard uncertainty, u | 5.3E-08 | m·s-2 |  |  |
| Degrees of freedom, eff (Welch-Satterthwaite formula) | 82 |   |  |  |
| Confidence level, p | 95% |   |  |  |
| Coverage factor, k (calculated with t-Student) | 1.99 |   |  |  |
| Expanded uncertainty (corrections applied), U = ku | 1.060E-07 | m·s-2 |  |  |
| Relative expanded uncertainty (corrections applied), Urel = U/g | 1.081E-08 |   |  |  |