An Improved Vertical Datum: a New Zealand Case Study
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National Geodetic Office

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Fabio Caratori Tontini | GNS Science
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• Traditional Levelling Based datums
• New Zealand Vertical Datum 2009
• Vertical Datum IMPROVEMENT PROJECT – NZVD 2016
• NATIONAL AIRBORNE GRAVITY SURVEY
• Summary
Introduction

• Vertical datum provides common reference surface
  – Essential for integration of geospatial data

• Geoid enables ellipsoidal height transformations
  – Geometric to gravimetric
  – Ellipsoidal - orthometric
TRADITIONAL LEVELLING BASED DATUMS
Levelling-based datums

- 13 levelling based datums
- Each connected to a tide separate tide gague based on “MSL”
- Not nationally consistent
- No national geoid
  - Need local transformations
- Gravimetric geoid using gravity observations to model geoid
- Independent of leveling
NEW ZEALAND VERTICAL DATUM 2009
New Zealand Quasigeoid 2009

- Gravimetric quasigeoid computed from:
  - EGM2008
New Zealand Quasigeoid 2009

- Gravimetric quasigeoid computed from:
  - EGM2008
  - Land and sea gravity data
New Zealand Quasigeoid 2009

- Gravimetric quasigeoid computed from:
  - EGM2008
  - Land and sea gravity data
  - DNSC08 altimetry
New Zealand Quasigeoid 2009

- Gravimetric quasigeoid computed from:
  - EGM2008
  - Land and sea gravity data
  - DNSC08 altimetry
  - Digital elevation model
New Zealand Quasigeoid 2009

- Subtract EGM2008 to give residual gravity anomalies
New Zealand Quasigeoid 2009

- Subtract EGM2008 to give residual gravity anomalies
- Fourier transform to convert residual gravity to residual geoid
New Zealand Quasigeoid 2009

- Subtract EGM2008 to give residual gravity anomalies
- Fourier transform to convert residual gravity to residual geoid
- Add back EGM2008 geoid
New Zealand Quasigeoid 2009

- Subtract EGM2008 to give residual gravity anomalies
- Fourier transform to convert residual gravity to residual geoid
- Add back EGM2008 geoid
- Result is NZGeoid2009
New Zealand Quasigeoid 2009

- Computation area:
  160° E – 170° W, 25° S – 60° S
- ~40m range over NZ
- Provided on 1’ x 1’ grid
  ~1.9 km over NZ
- NZGeoid2009 value linearly interpolated from grid
- Geoid changes smaller than 2 km will not be represented
New Zealand Vertical Datum 2009

- Based on NZGeoid2009
- Includes official offsets to 13 main local vertical datums
- Normal-orthometric heights
- Transformation to GRS80
- 8cm nominal accuracy

<table>
<thead>
<tr>
<th>Datum</th>
<th>Offset</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Tree Point 1964</td>
<td>0.06</td>
<td>0.03</td>
</tr>
<tr>
<td>Auckland 1946</td>
<td>0.34</td>
<td>0.05</td>
</tr>
<tr>
<td>Moturiki 1953</td>
<td>0.24</td>
<td>0.06</td>
</tr>
<tr>
<td>Gisborne 1926</td>
<td>0.34</td>
<td>0.02</td>
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<tr>
<td>Napier 1962</td>
<td>0.20</td>
<td>0.05</td>
</tr>
<tr>
<td>Taranaki 1970</td>
<td>0.32</td>
<td>0.05</td>
</tr>
<tr>
<td>Wellington 1953</td>
<td>0.44</td>
<td>0.04</td>
</tr>
<tr>
<td>Nelson 1955</td>
<td>0.29</td>
<td>0.07</td>
</tr>
<tr>
<td>Lyttelton 1937</td>
<td>0.47</td>
<td>0.09</td>
</tr>
<tr>
<td>Dunedin 1958</td>
<td>0.49</td>
<td>0.07</td>
</tr>
<tr>
<td>Dunedin-Bluff 1960</td>
<td>0.38</td>
<td>0.04</td>
</tr>
<tr>
<td>Bluff 1955</td>
<td>0.36</td>
<td>0.05</td>
</tr>
<tr>
<td>Stewart Island 1977</td>
<td>0.39</td>
<td>0.15</td>
</tr>
</tbody>
</table>
Vertical Datum IMPROVEMENT PROJECT – NZVD 2016
NZVD2009 limitations

- Irregular gravity coverage
- Computed from existing gravity data
- Gravity not collected for geoid determination
NZVD2009 limitations

- Sparse GNSS-levelling data
- Extensive precise levelling coverage
NZVD2009 limitations

- Simplistic offset modelling
- Other options available
- Multiple datums confusing
Is this a problem?

- Confusion still exists with multiple datums
- Datum accuracy insufficient
- Timely disaster response difficult
- Heights becoming more important
Disaster recovery

- Heights are important after disaster events
- Expectation that height system exists to aid recovery
- Quick re-establishment of height system necessary
- Not efficient with levelling based datum
3D cadastre

- Heighted boundaries
  - Variety of datums used
  - Often inconsistent with other services
- Geoid not accurate enough
3D cadastre

- Heighted boundaries
  - Variety of datums used
  - Often inconsistent with other services
- Geoid not accurate enough
- Future cadastre may need greater height consistency
  - All rights shown together
  - All measurements 3D
User Requirements Accuracies

- Cadastral Surveyors
- Local Government
- Hydrographic Charting
- Recreational GNSS
- Scientific Monitoring
- GIS Community
- Topographic Mapping
An improved vertical datum

- Better accuracy
- Better links to existing datums
- Better services to access datum
Better accuracy

- Updated national geoid
- 3cm in developed areas
- National airborne gravity coverage
- New global models and computation techniques
Better links to existing datums

- Present approach simplistic
- Accuracy improved by GNSS-levelling
- Alternative modelling approaches
Better services to access datum

**MARK IDENTIFICATION**

- **Code:** BWKW
- **Name:** SM 271 SO 49263
- **Country:** New Zealand
- **Land District:** North
- **Topo50 sheet:** Auckland
- **NZTM:** 5919051 1743941

**NZGD 2000 COORDINATES**

- **Latitude:** 36° 51' 48.64526" S
- **Longitude:** 174° 36' 53.29972" E
- **Order:** 4
- **Authorised:** 16-Aug-2000
- **Reference:** 199910102: Auckland 4th Control

<table>
<thead>
<tr>
<th>Circuit</th>
<th>Northing (m)</th>
<th>Easting (m)</th>
<th>Scale Factor</th>
<th>Convergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mount Eden</td>
<td>801 788.276</td>
<td>386 682.713</td>
<td>0.9999022</td>
<td>-0° 05' 22&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HEIGHT DATA</th>
<th>Height (m)</th>
<th>Order</th>
<th>Calculation Date</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auckland Vertical Datum 1946</td>
<td>19.510</td>
<td><strong>2V</strong></td>
<td>27-Nov-1974</td>
<td>SO 49263</td>
</tr>
</tbody>
</table>
NATIONAL AIRBORNE GRAVITY SURVEY
Airborne Gravity Collection

Collaboration with:
Victoria University of Wellington
GNS Science

2014
• Gravity Flights completed

2015
• LVD offset improvement
• Geoid computation
• Transformation tools

2016
• New vertical datum
Gravity collection

- Piper Chieftain
  - 6 hour endurance
  - 130 knots
- L&R Air-Sea Gravimeter
  - 2 mGal repeatability
Collection challenges

- Wind, rain, fog
- Aircraft mechanicals
- Limited daylight
- Average of 3 flight days per week
Flight lines

• 50,000 line km
  – 120 flight lines at 10k spacing
  – 20 tie lines at 150k spacing
  – 2 calibration lines
• 4 base airports
• Two campaigns
  – August – October 2013
  – February – June 2014
• 75 flights
• 425 flying hours
Flight Tasks

- Aligned to topography
- Flying height 3,500 – 13,500 feet
Free Air Anomaly – EGM2008
Free Air Anomaly – Airborne Data
Data Combination

Combined airborne and terrestrial gravity observations (mGal) using least squares collocation.
Data Combination

Difference between combined airborne/terrestrial data and EGM2008 (mGal)

Highlights the fine scale structure of the NZ gravity field and that the main areas of difference are in the mountainous parts of the South Island
SUMMARY
Summary

- Airborne gravity campaign is now complete
- Should deliver 3 cm geoid
- Improvements to LVD offsets also underway
- Updated NZ vertical datum expected in 2016
QUESTIONS