An Improved Vertical Datum: a New Zealand Case Study

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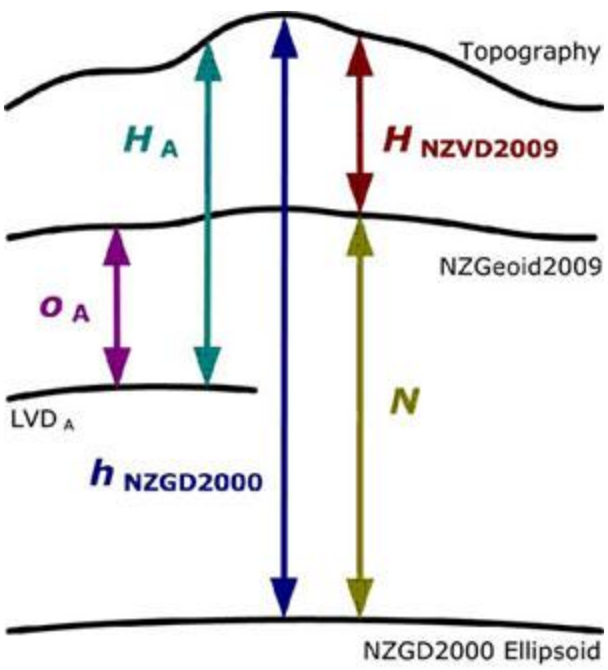
- **Introduction**
- **Traditional LevellinG Based datums**
- **New Zealand Vertical Datum 2009**
- **Vertical Datum IMPROVEMENT PROJECT – NZVD 2016**
- **NATIONAL AIRBORNE GRAVITY SURVEY**
- **Summary**

Introduction

- Vertical datum provides common reference surface
  - Essential for integration of geospatial data
- Geoid enables ellipsoidal height transformations
  - Geometric to gravimetric
  - Ellipsoidal - orthometric



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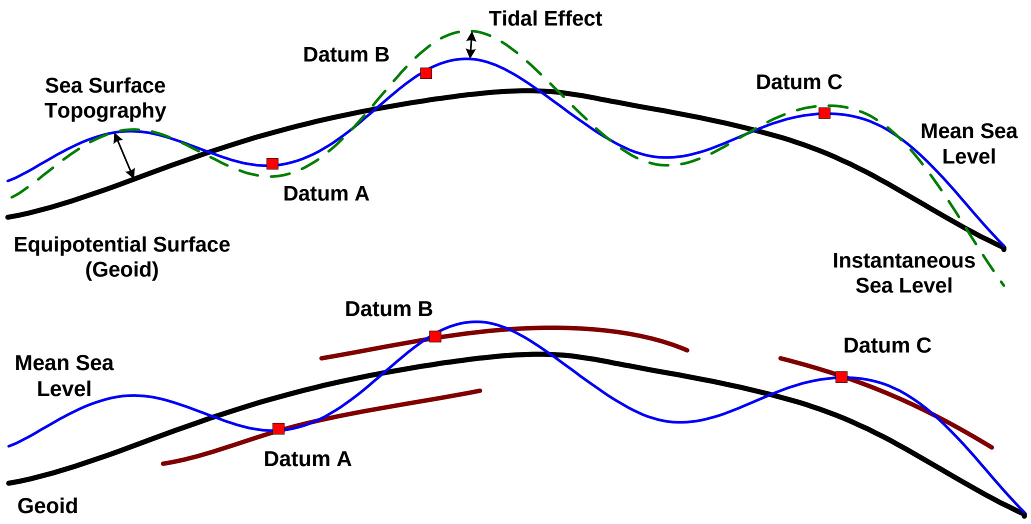
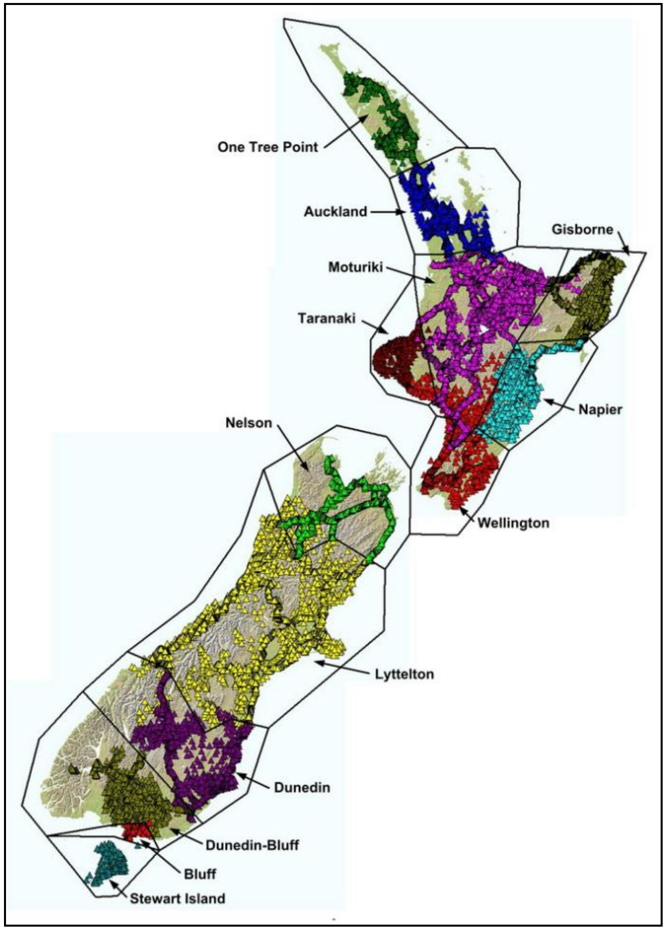
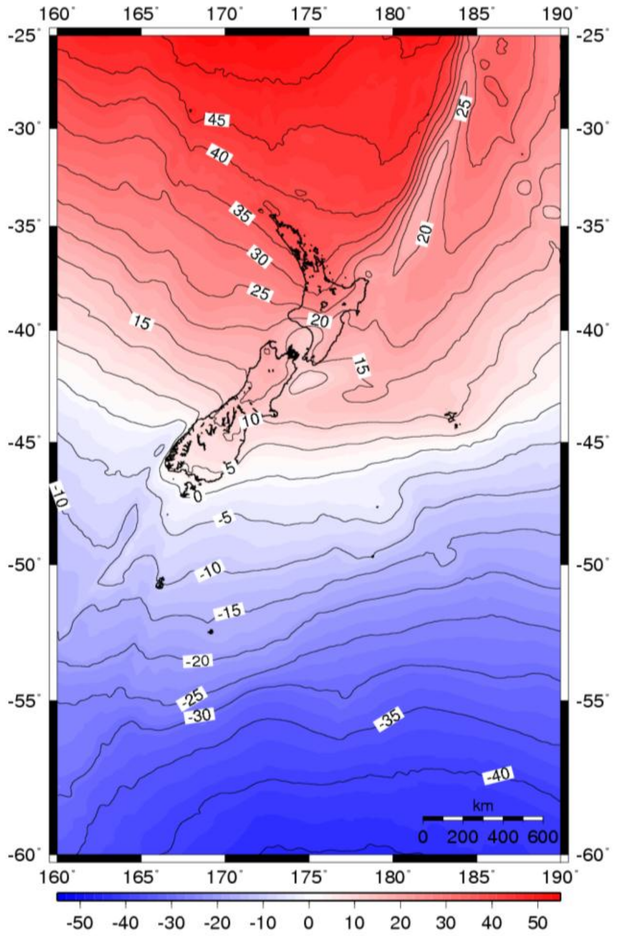
TRADITIONAL LEVELLING BASED DATUMS

Levelling-based datums

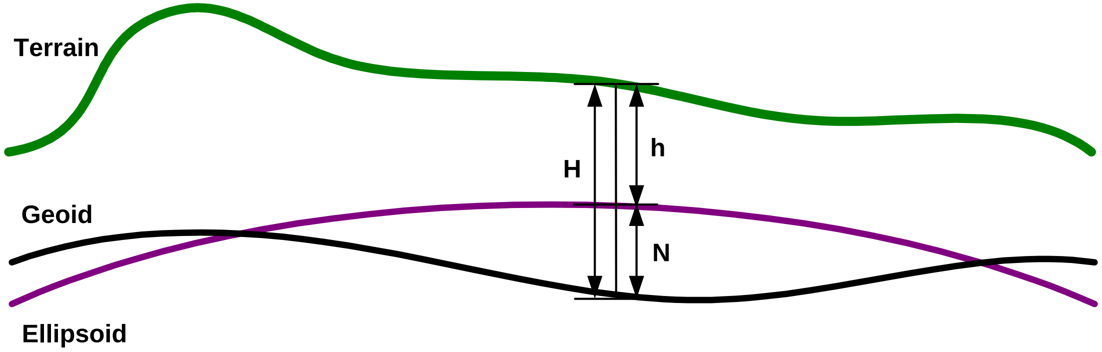
- 13 levelling based datums
- Each connected to a tide separate tide gague based on “MSL“
- Not nationally consistent
- No national geoid
  - Need local transformations







- Gravimetric geoid using gravity observations to model geoid
- Independent of leveling



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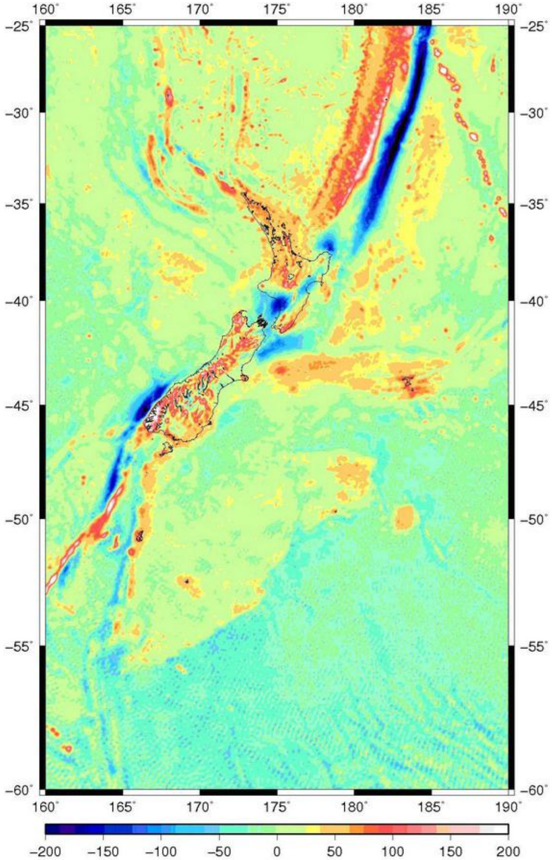
NEW ZEALAND VERTICAL DATUM 2009

New Zealand Quasigeoid 2009

- Gravimetric quasigeoid computed from:
  - EGM2008



New Zealand Quasigeoid 2009

- Gravimetric quasigeoid computed from:
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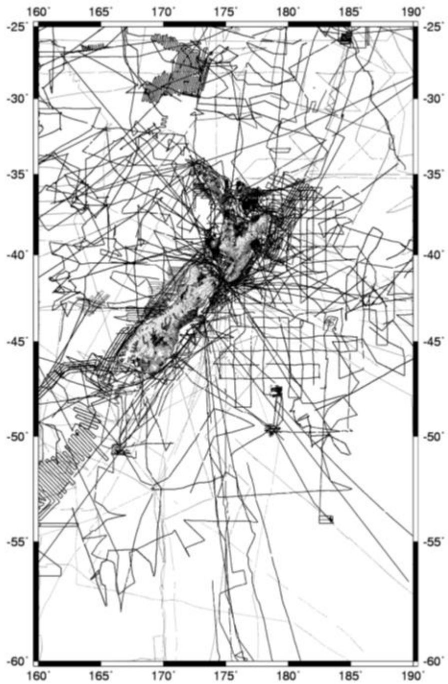
  - Land and sea gravity data



New Zealand Quasigeoid 2009

- Gravimetric quasigeoid computed from:
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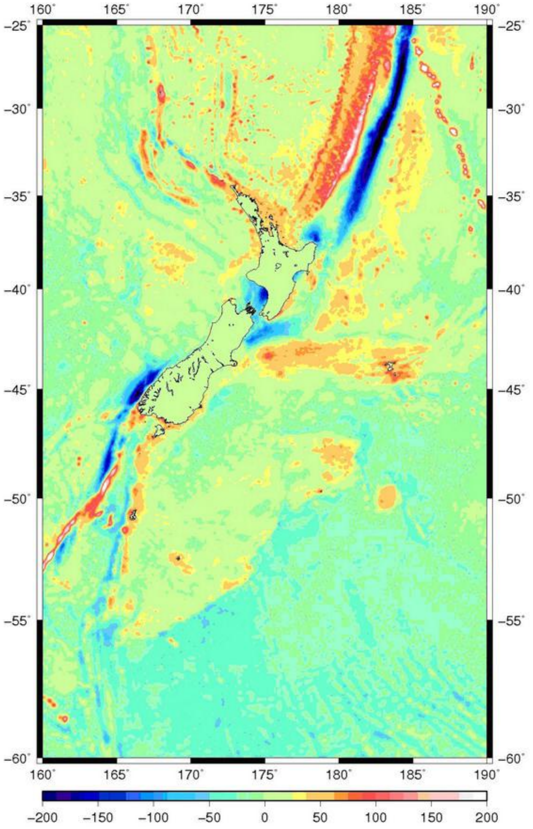
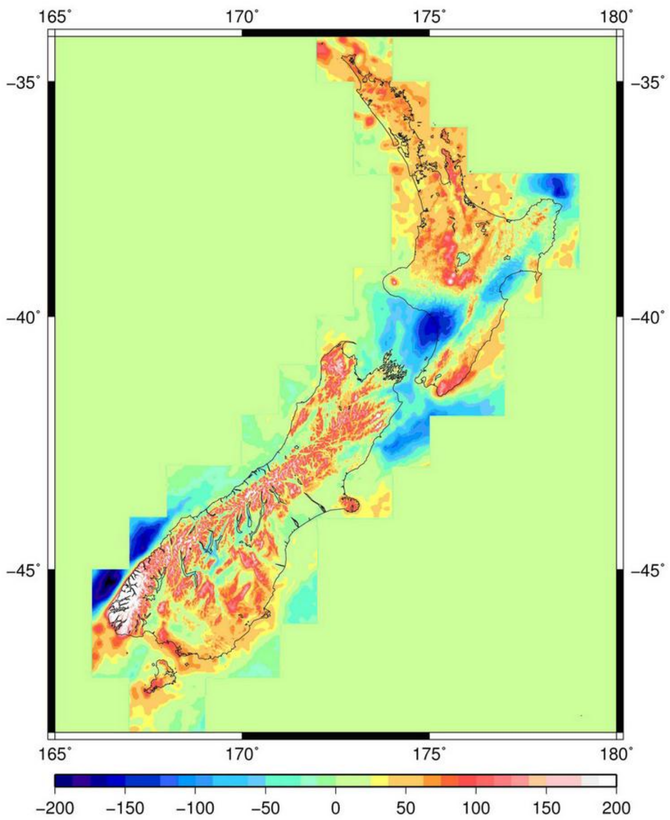
  - Land and sea gravity data
  - DNSC08 altimetry



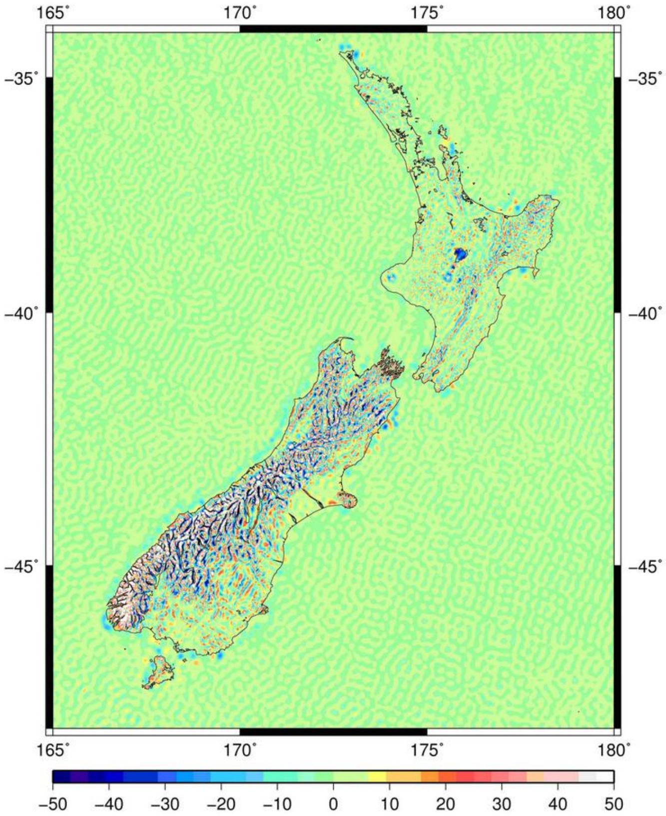
New Zealand Quasigeoid 2009

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



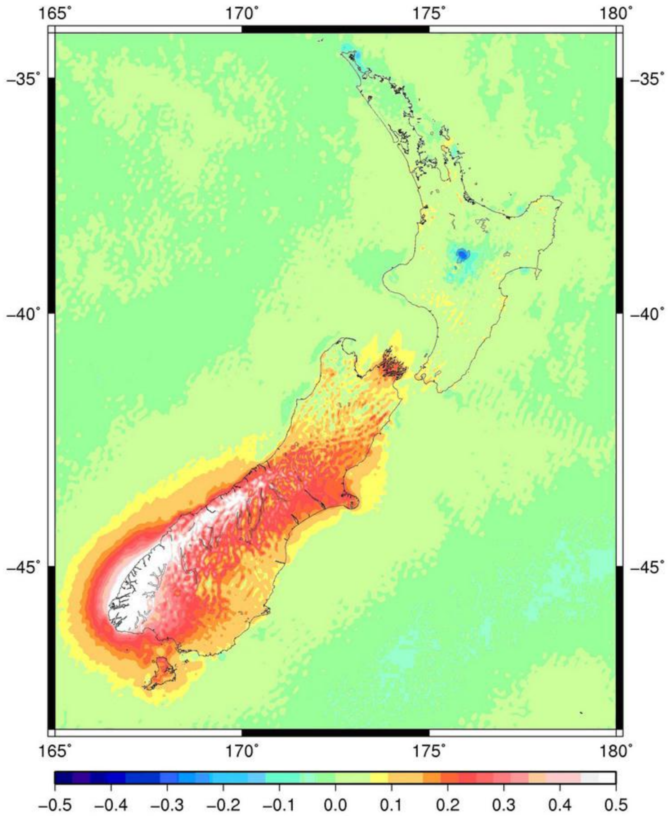
New Zealand Quasigeoid 2009

- Subtract EGM2008 to give residual gravity anomalies



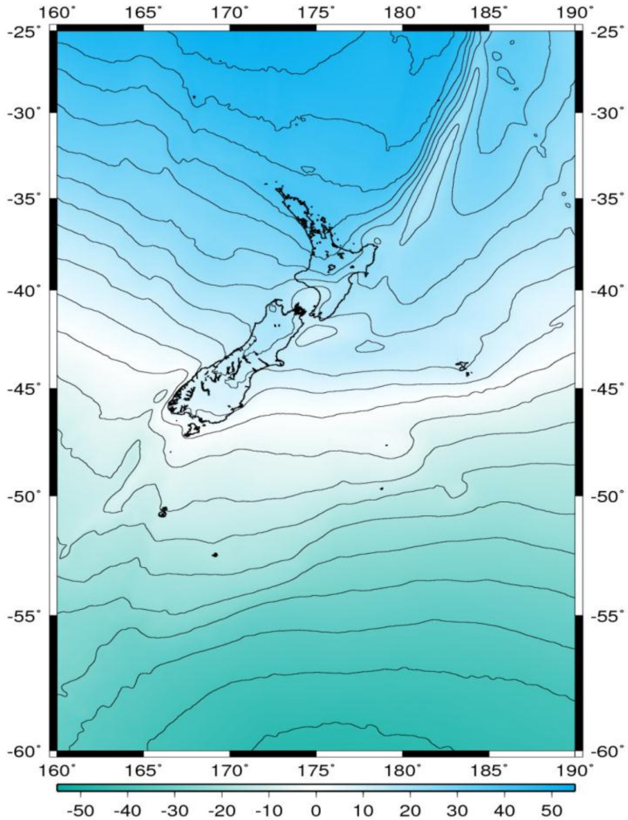
New Zealand Quasigeoid 2009

- Subtract EGM2008 to give residual gravity anomalies
- Fourier transform to convert residual gravity to residual geoid



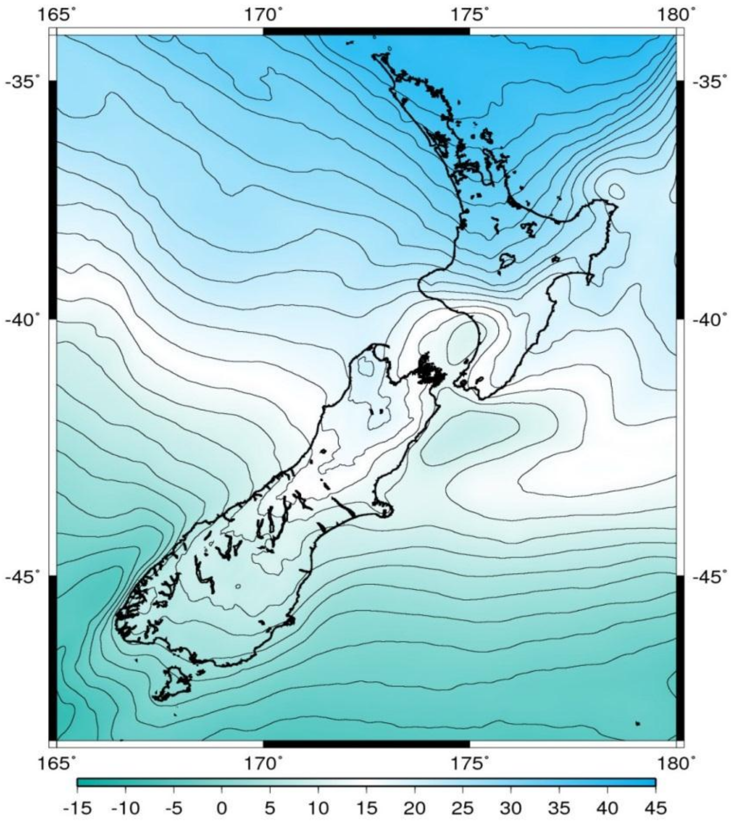
New Zealand Quasigeoid 2009

- Subtract EGM2008 to give residual gravity anomalies
- Fourier transform to convert residual gravity to residual geoid
- Add back EGM2008 geoid



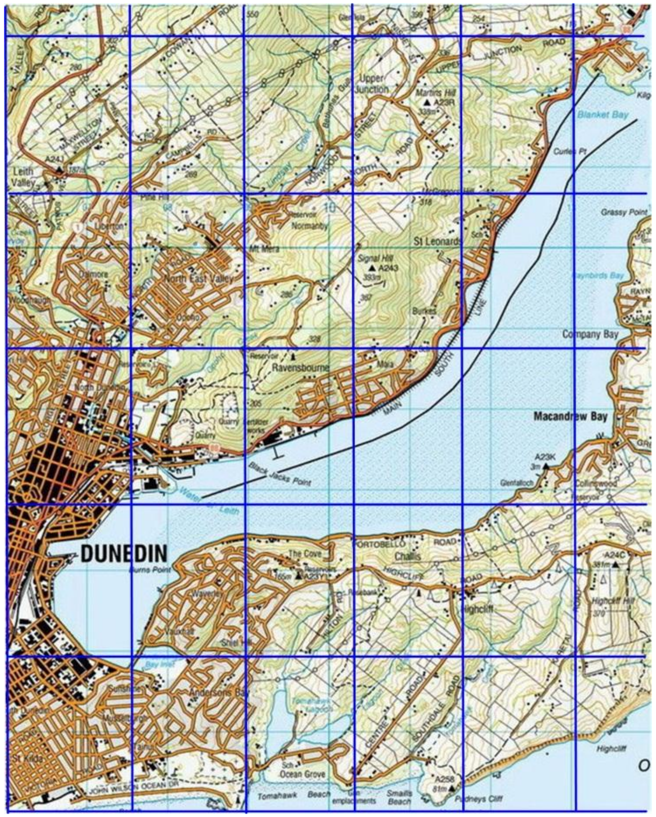
New Zealand Quasigeoid 2009

- 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:
  160º E – 170º W, 25º S – 60º 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

Datum	Offset	Std Dev
One Tree Point 1964	0.06	0.03
Auckland 1946	0.34	0.05
Moturiki 1953	0.24	0.06
Gisborne 1926	0.34	0.02
Napier 1962	0.20	0.05
Taranaki 1970	0.32	0.05
Wellington 1953	0.44	0.04
Nelson 1955	0.29	0.07
Lyttelton 1937	0.47	0.09
Dunedin 1958	0.49	0.07
Dunedin-Bluff 1960	0.38	0.04
Bluff 1955	0.36	0.05
Stewart Island 1977	0.39	0.15

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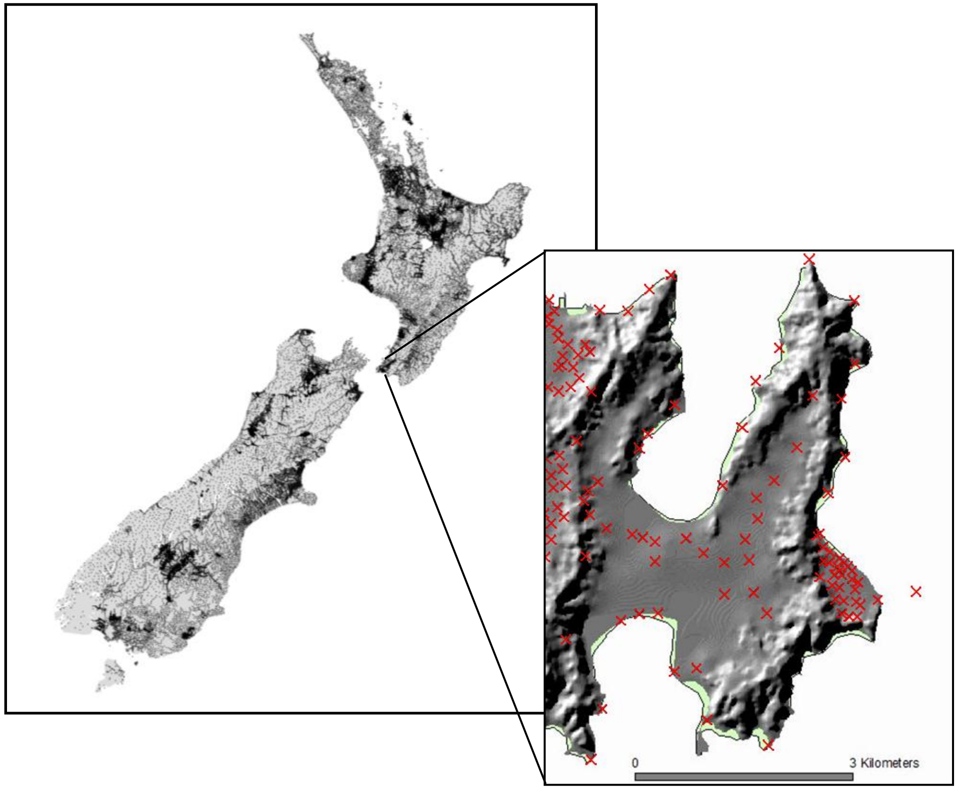
Vertical Datum IMPROVEMENT PROJECT – NZVD 2016

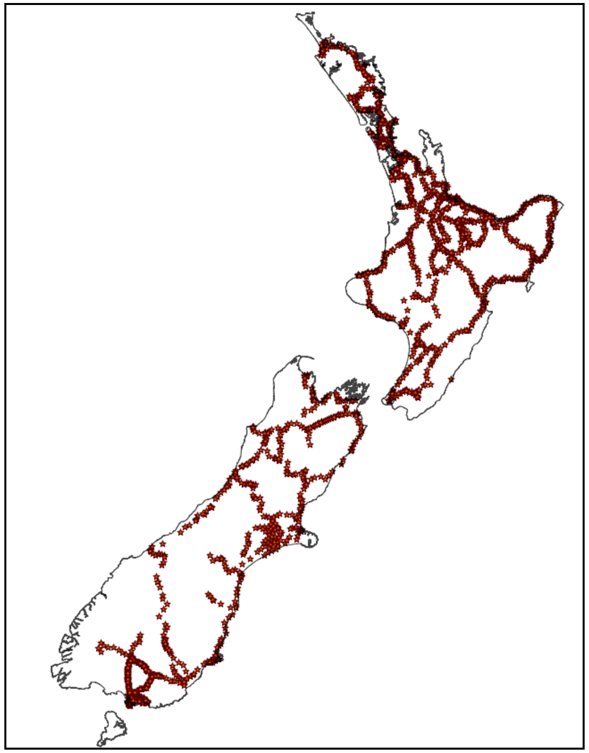
NZVD2009 limitations

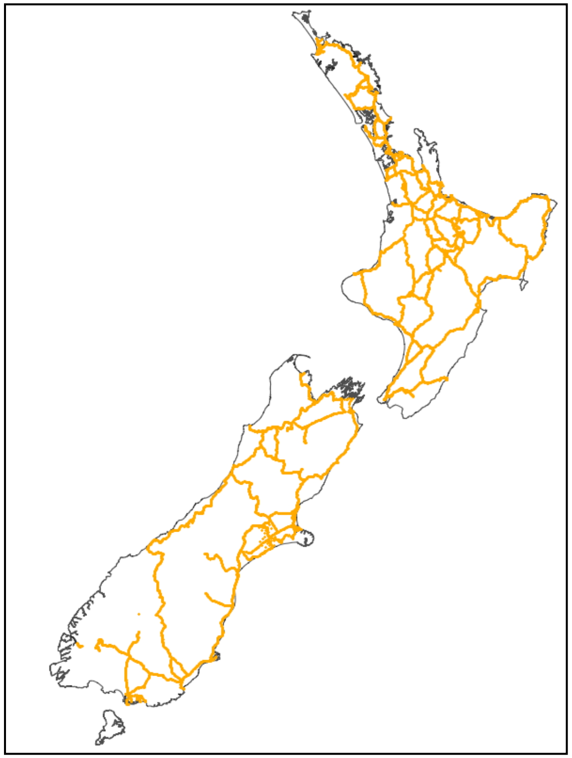
- Irregular gravity coverage
- Computed from existing gravity data
- Gravity not collected for geoid determination



NZVD2009 limitations

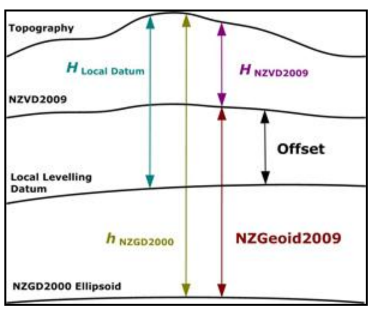
- Sparse GNSS-levelling data
- Extensive precise levelling coverage



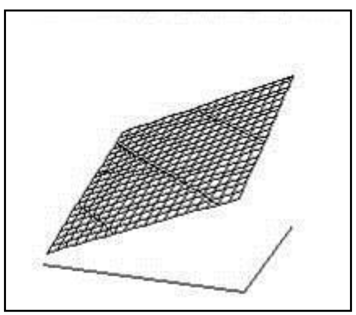


NZVD2009 limitations

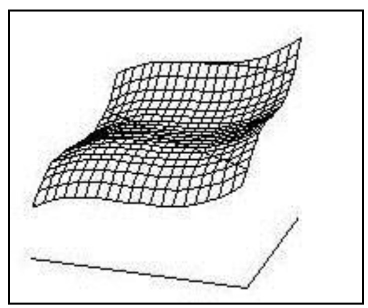
- Simplistic offset modelling
- Other options available
- Multiple datums confusing



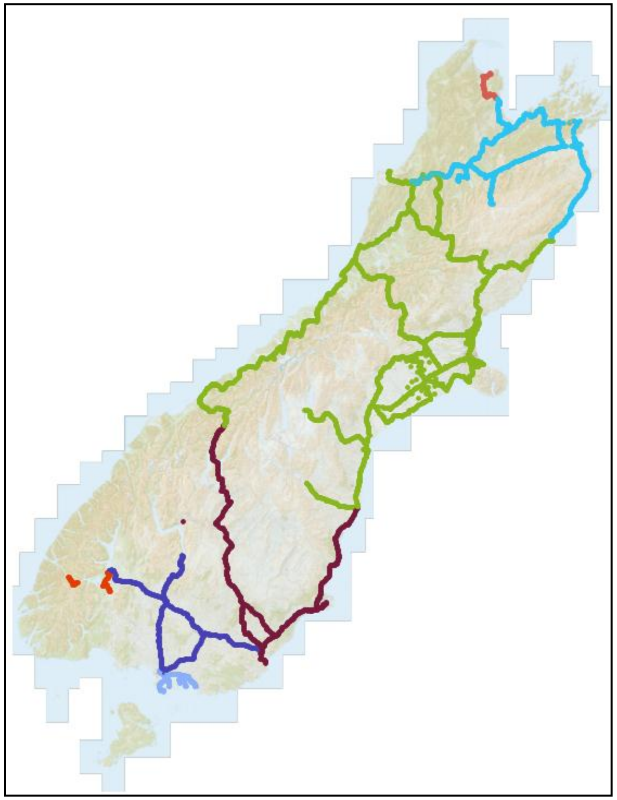
Point



Inclined Plane



Polynomial Surface



Is this a problem?

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

AEXF: Mark details

MARK IDENTIFICATION

Code:	AEXF	Country:	New Zealand
Name:	LA 41	Land District:	Wellington
Alternatives:	SANSON	Topo50 sheet:	BM34
		NZTM:	5544997 1806295

NZGD 2000 COORDINATES

Latitude:	40° 13' 12.25421" S	Order:	3
Longitude:	175° 25' 28.01643" E	Authorised:	28-Jul-1999
Ellipsoidal height (m):	66.805	Reference:	

Circuit	Northing (m)	Easting (m)	Scale Factor	Convergence
Wanganui Circuit 2000	802 426.909	394 585.868	1.0000004	-0° 02' 27"

ORTHOMETRIC HEIGHTS

Height datum	Height (m)	Order	Calculation Date	Reference
Taranaki Vertical Datum 1970	54.9623	1V	31-Dec-1978	Lev 3/172
Wellington Vertical Datum 1953	55.0646	1V	30-Nov-1965	Wn 4/69
Moturiki Vertical Datum 1953	54.9436	1V	30-Nov-1965	Wn 4/11

MARK DETAILS

Last maintained:	4-Jul-1997
Maintenance level:	
Mark status:	Reliably Placed/Found
Description:	Hemispherical stainless steel pin set in concrete block below cast iron cover in grass.24-Oct-1998: SS pin in conc in box, 0.3m below GL. ID plaque attached.9-Jul-1999: ID plate attached IN FOOTPATH ON NORTH EAST CORNER OF INTERSECTION WITH S.H. 1 AND S.H. 3 GPS - marginal, advertising sign and building close to mark
Beacon type:	Not Beaconed
Protection type:	

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

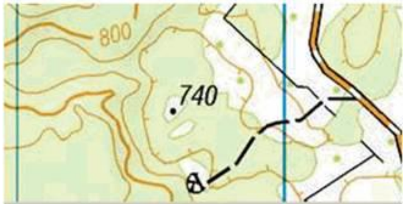
Hydrographic Charting

Recreational GNSS

Scientific Monitoring

GIS Community

Topographic Mapping

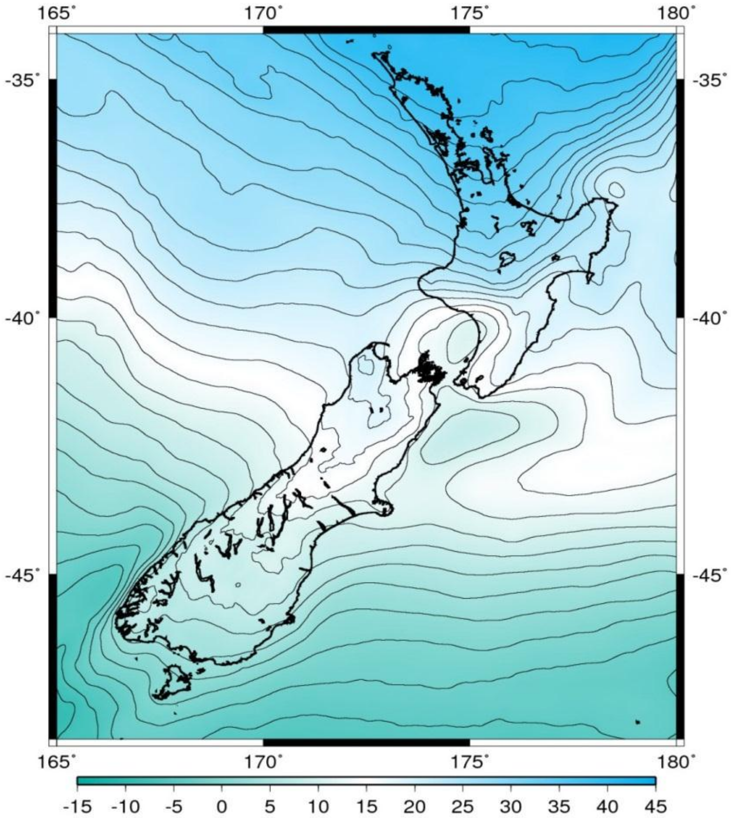


An improved vertical datum

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

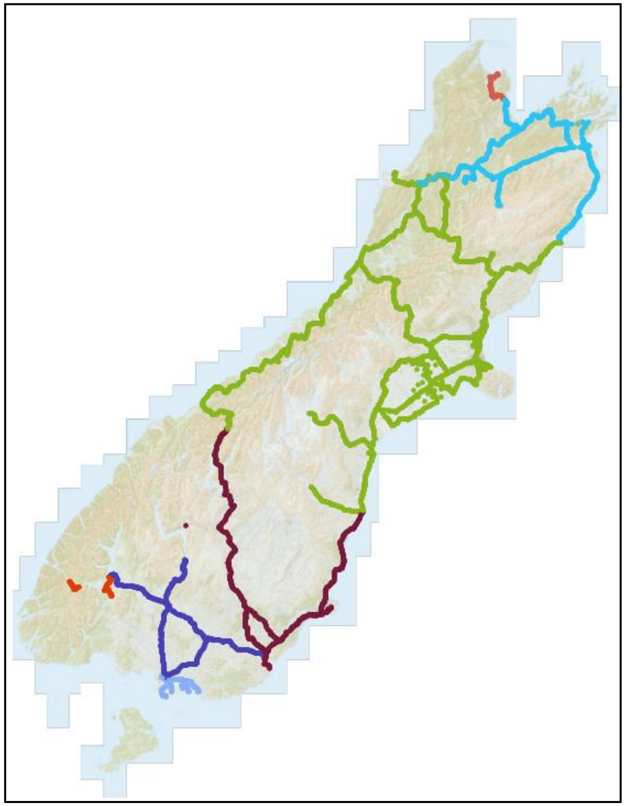
Better accuracy

- 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

BWKW: Mark details

MARK IDENTIFICATION

Code:	**BWKW**	Country:	**New Zealand**
Name:	**SM 271 SO 49263**	Land District:	**North Auckland**
Alternatives:		Topo50 sheet:	**BA31**
		NZTM:	**5919051 1743941**

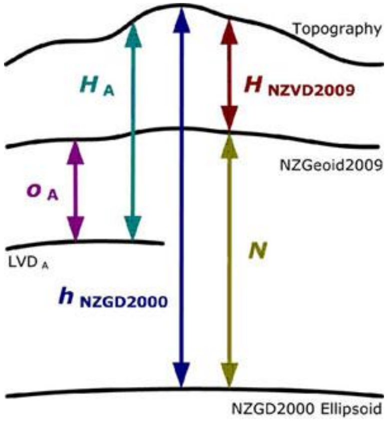
NZGD 2000 COORDINATES

Latitude:	**36° 51' 48.64528" S**	Order:	4	Historical values
Longitude:	**174° 36' 53.29972" E**	Authorised:	**16-Aug-2000**	
Ellipsoidal height (m):	**53.357**	Reference:	**199910102: Auckland 4th Control**	

Circuit	Northing (m)	Easting (m)	Scale Factor	Convergence	
Mount Eden Circuit 2000	**801 788.276**	**386 682.713**	**0.9999022**	**-0° 05' 22"**	Historical values

ORTHOMETRIC HEIGHTS

Height datum	Height (m)	Order	Calculation Date	Reference
Auckland Vertical Datum 1946	**19.510**	2V	**27-Nov-1974**	**SO 49263**



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

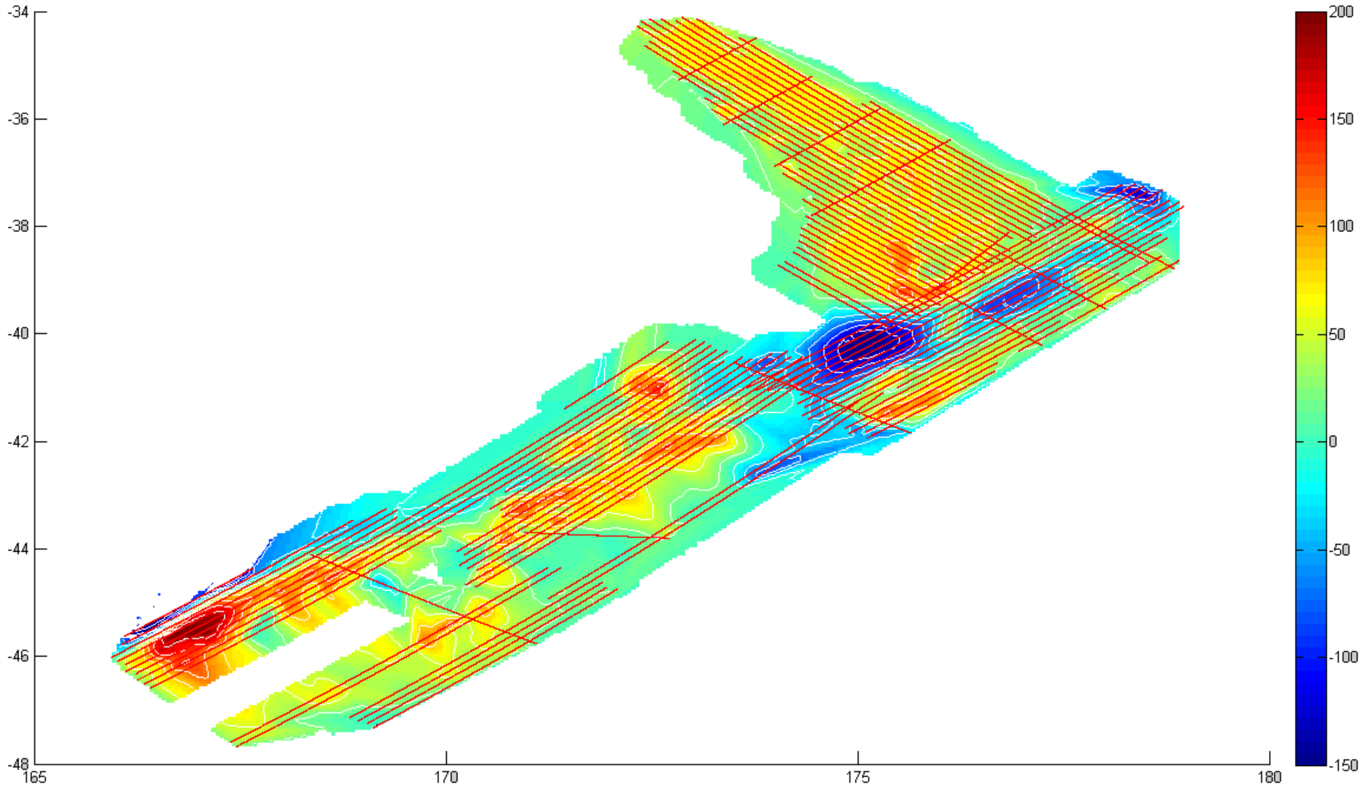
Flight lines

- 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

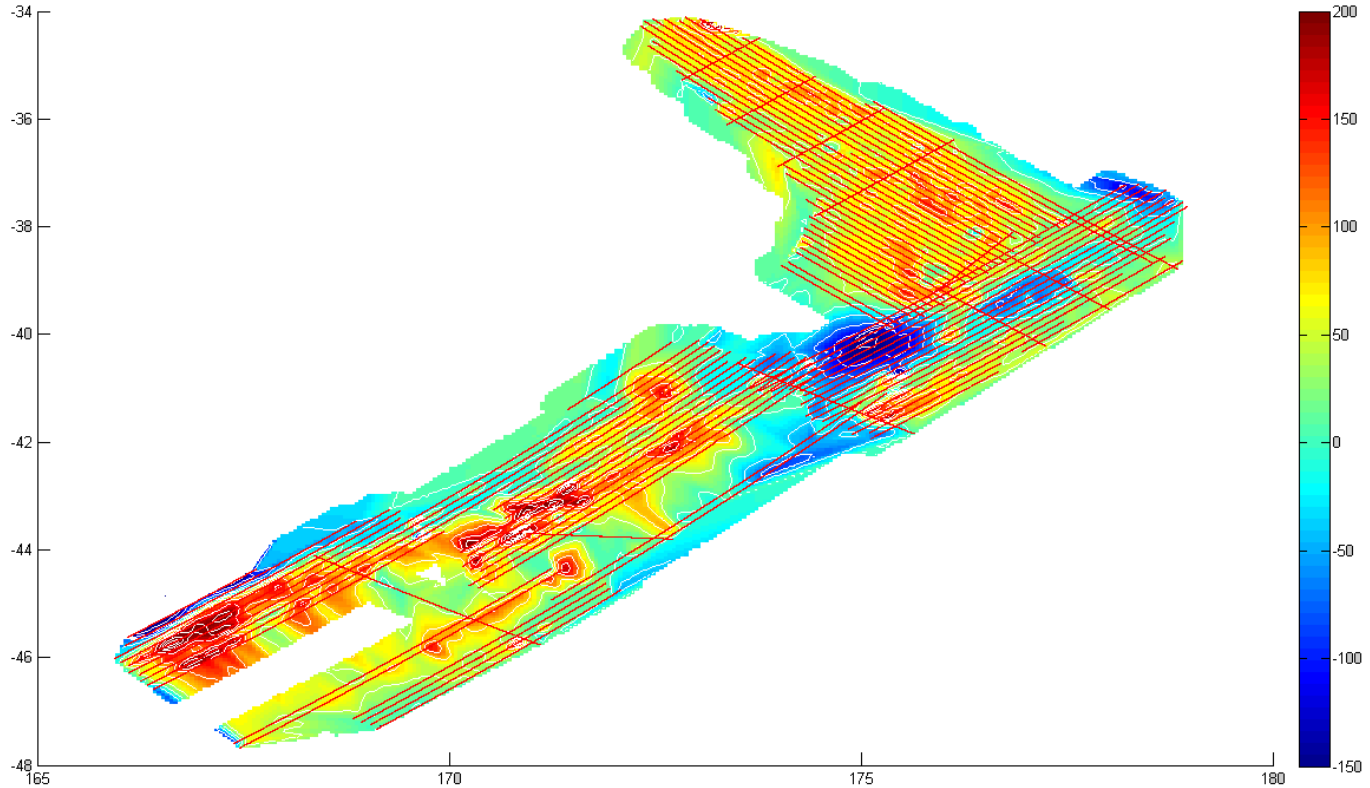
Flight Tasks

- Aligned to topography
- Flying height 3,500 – 13,500 feet

Free Air Anomaly – EGM2008

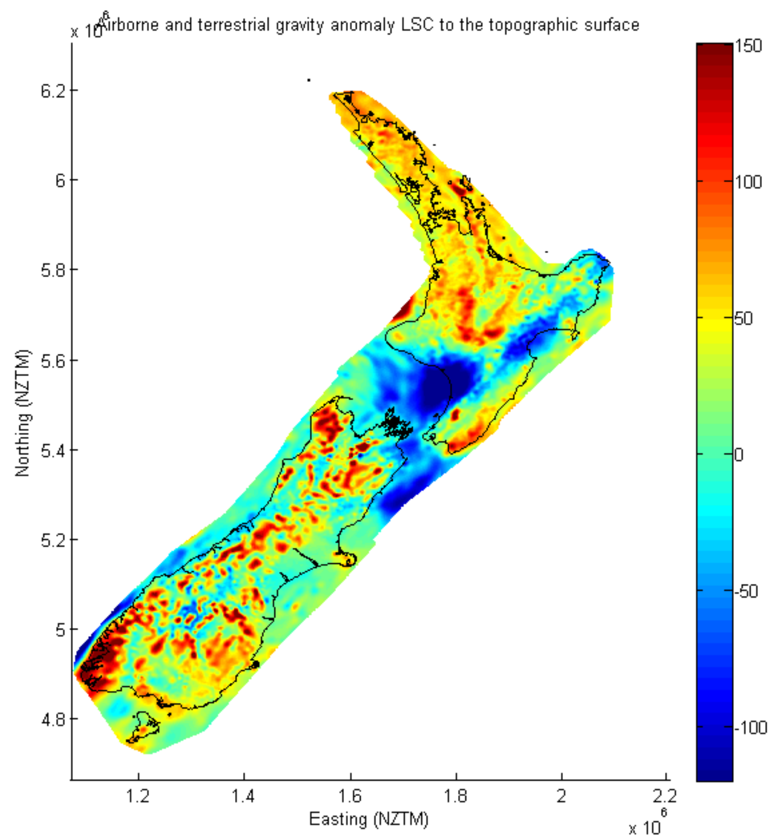


Free Air Anomaly – Airborne Data



Data Combination

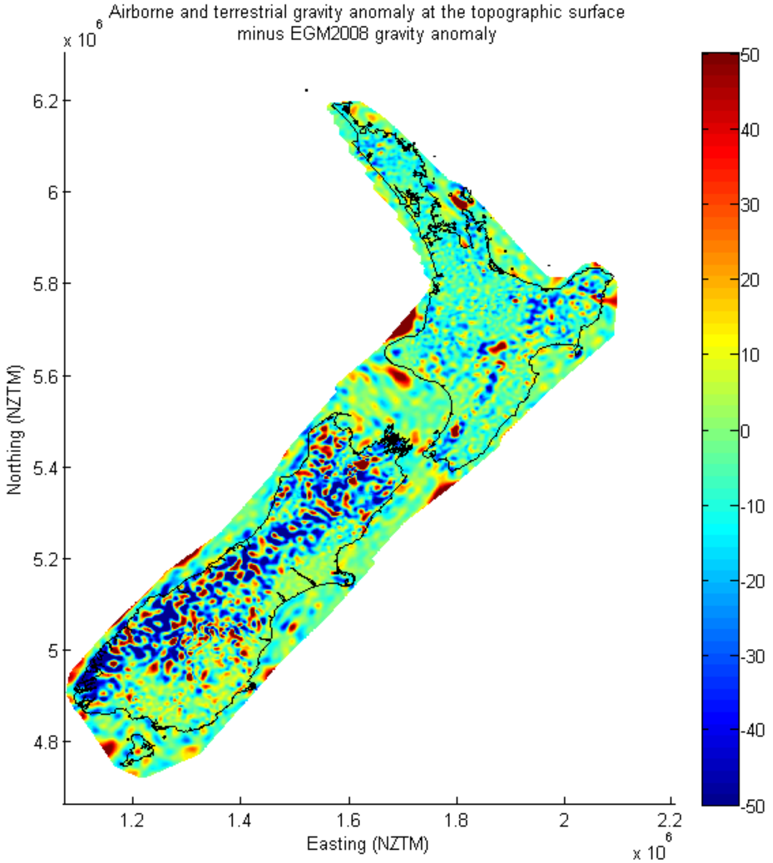
Combined aitborne and terrestrial gravity observations (mGal) using least squares collocation



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

FIG Working Week

Christchurch
New Zealand
2–6 May 2016

Recovery from a natural disaster

QUESTIONS