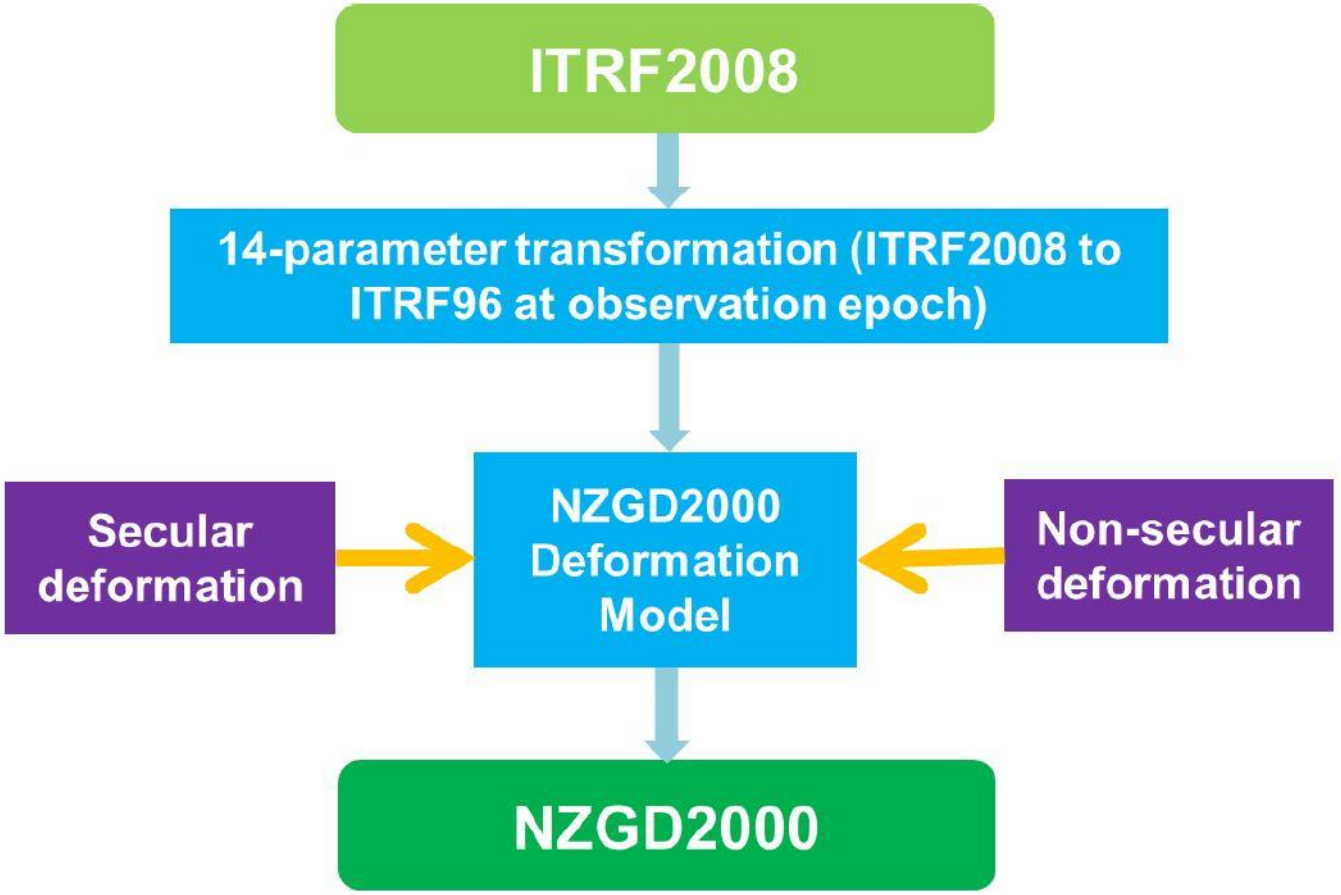
Case study: the Kaikoura 2016 earthquake in New Zealand

Chris Crook: Land Information New Zealand

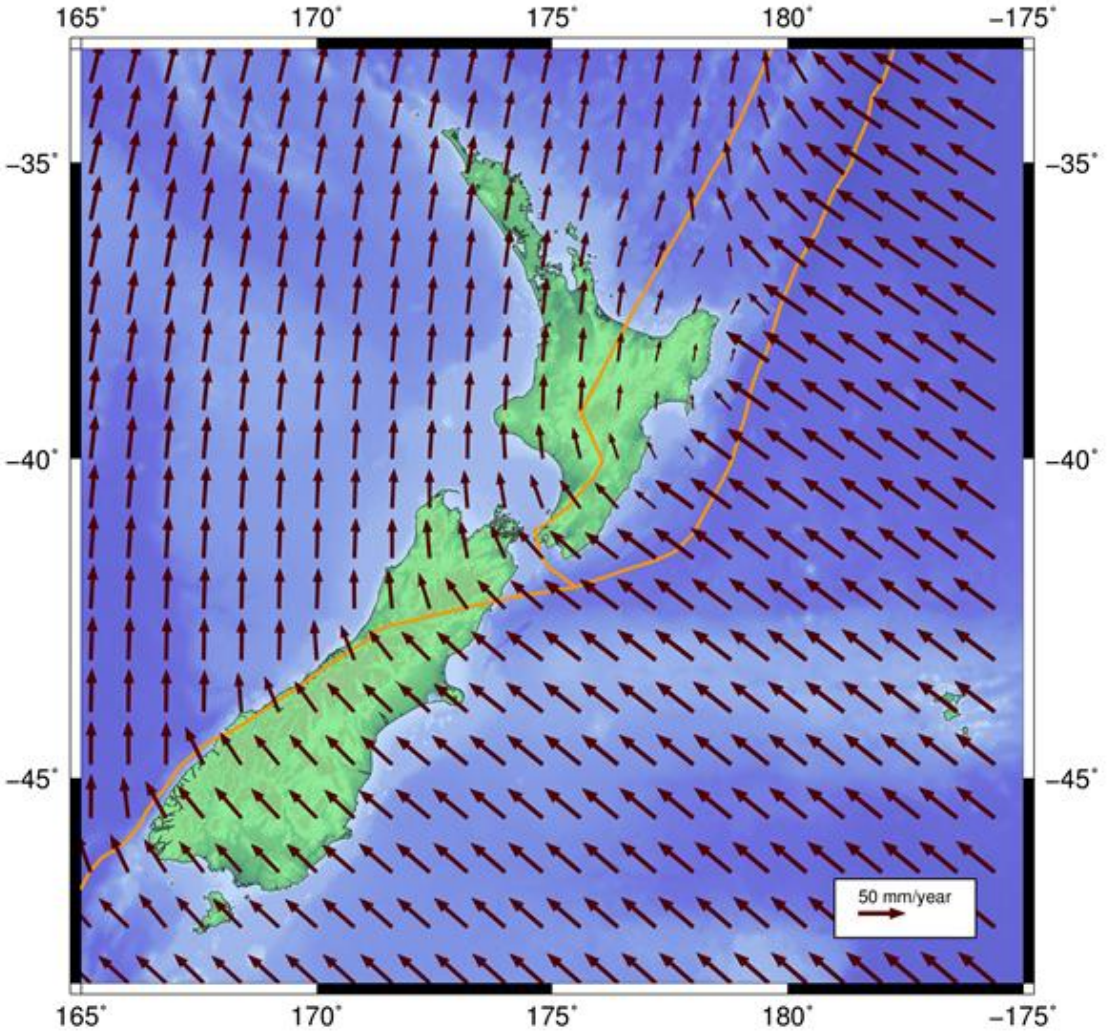
Nic Donnelly: Land Information New Zealand

NZGD2000


ITRF2008
14-parameter transformation (ITRF2008 to ITRF96 at observation epoch)
Secular deformation
NZGD2000 Deformation Model
Non-secular deformation
NZGD2000

NZGD2000 – deformation model

- Coordinates are fixed, except after an earthquake
- Deformation model manages tectonic movements
- New versions of deformation model published after earthquakes or when new data is available



NZGD2000 versions

Version	Reason
20000101	National deformation model - initial version
20130801	Update of national deformation model and patches for: Reverse patches for the following events: Dusky Sound, 2009 Darfield (Christchurch), September 2010 Christchurch, February 2011 Christchurch, June 2011 Christchurch, December 2011 + 3 other earthquakes
20140201	Patches for events: Cook Strait, 17 July 2013 Lake Grassmere, 16 August 2013
20160701	Reverse patches Christchurch, 14 February 2016
20170601	*Hybrid patch for Kaikoura 14 November 2016*

The 2016 M7.8 Kaikoura eq

- Magnitude 7.8, 14 November 2016
- Multiple faults ruptured
- Displacements exceeding 5m (horizontal and vertical)
- Serious property and infrastructure damage
- Infrastructure includes spatial reference system (datum)

Social setting

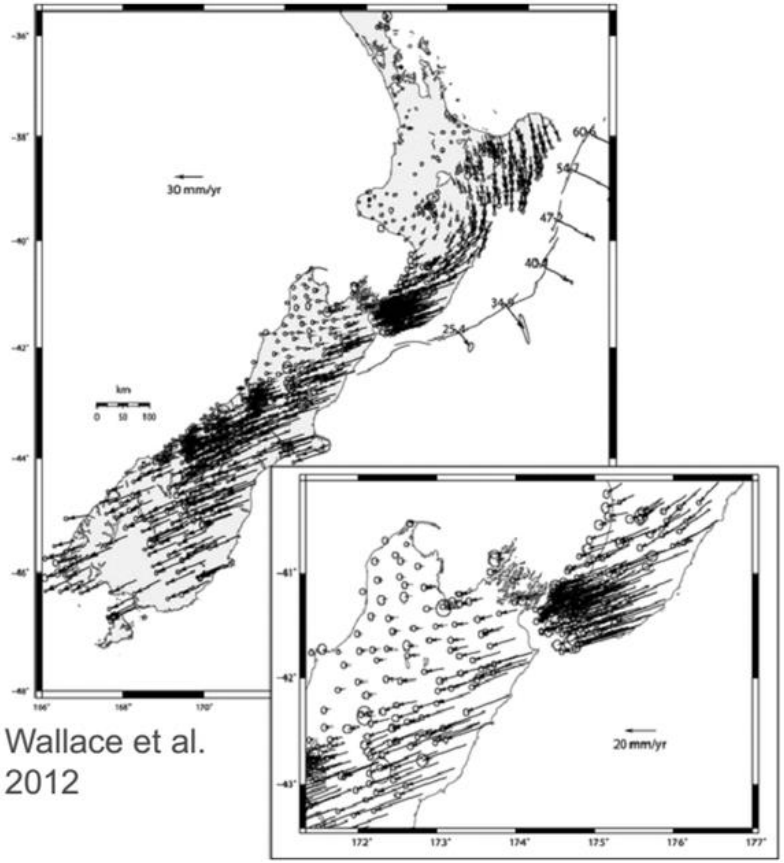
100 km

Blenheim 31,000
Seddon 500
Kaikoura 2,100
Christchurch 390,000

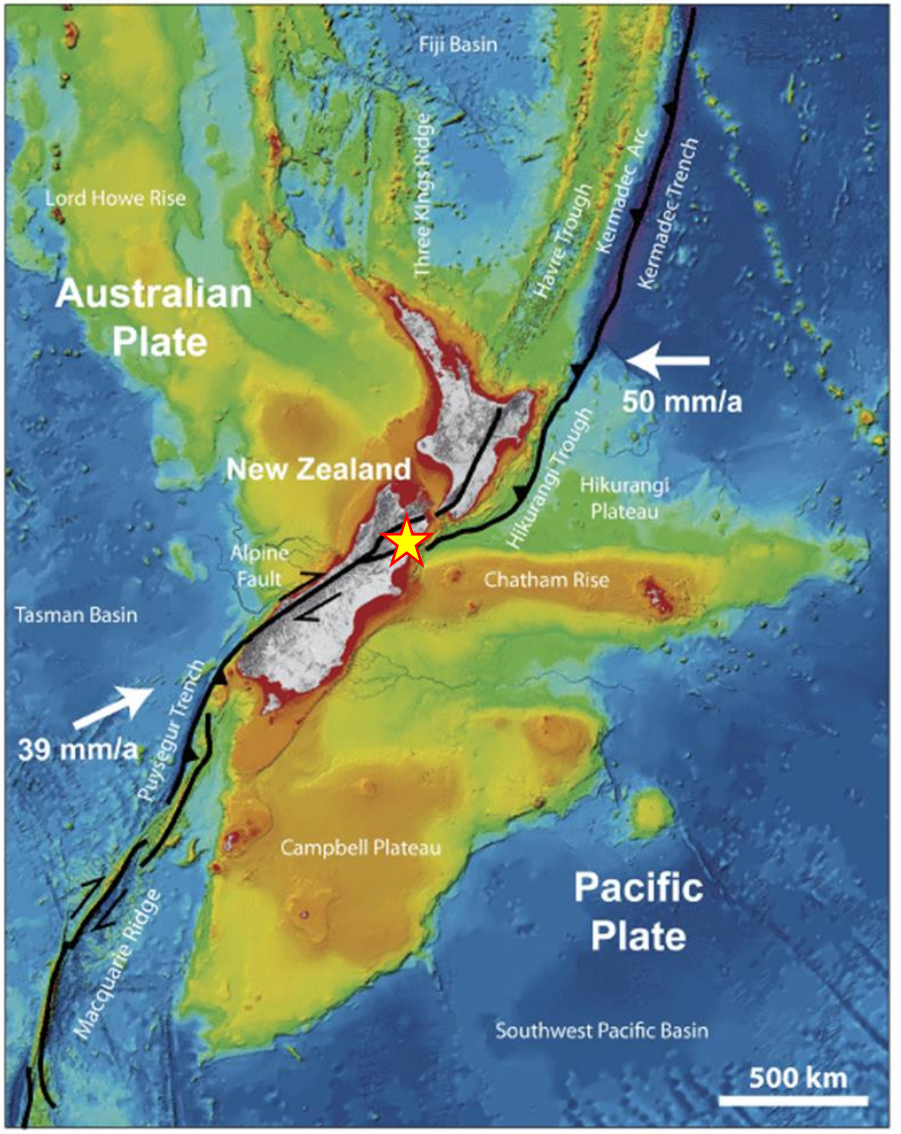
Images: stuff.co.nz

Tectonic setting

New Zealand tectonics are dominated by the continued collision between the Pacific and Australian plates.

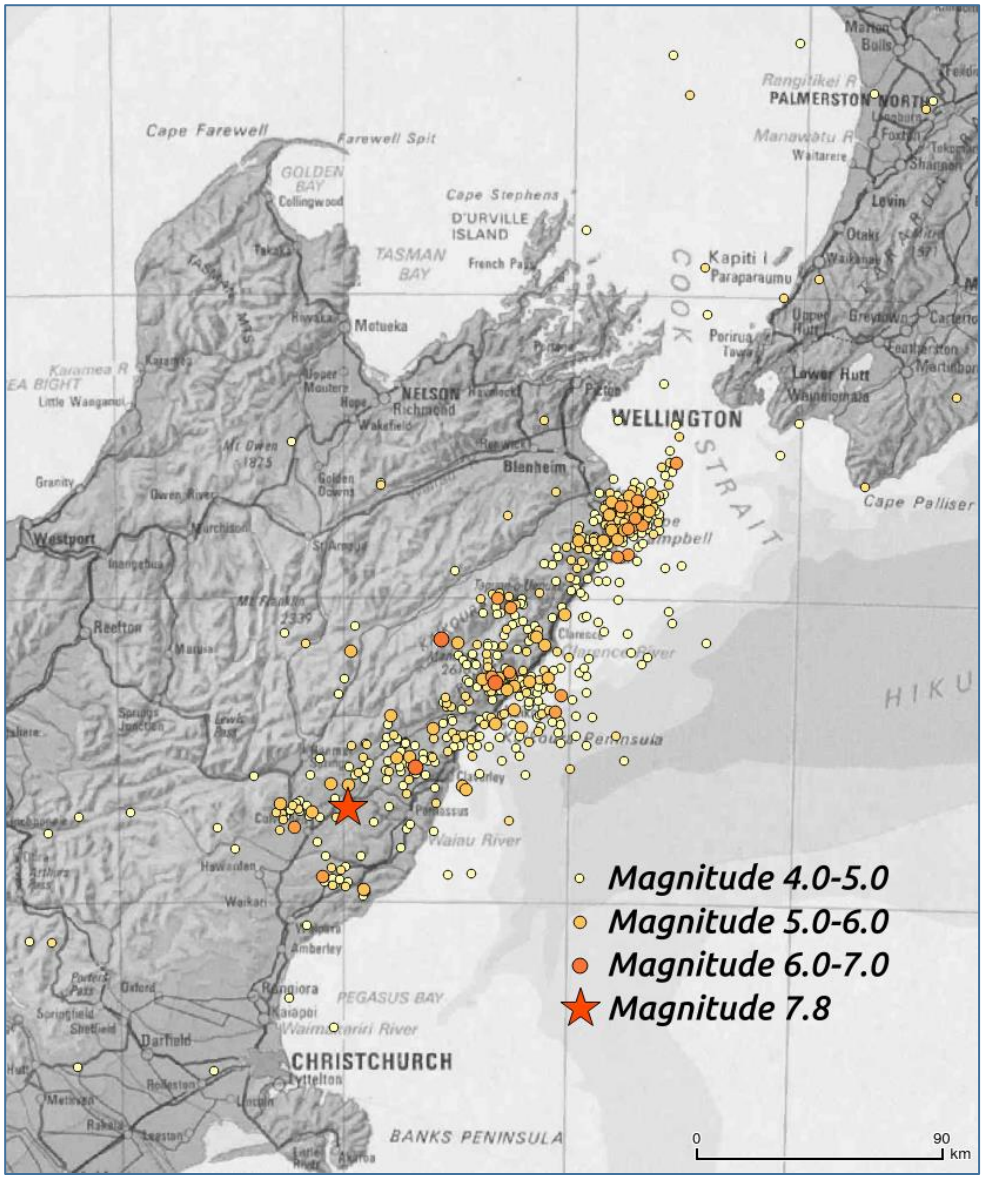


Wallace et al. 2012

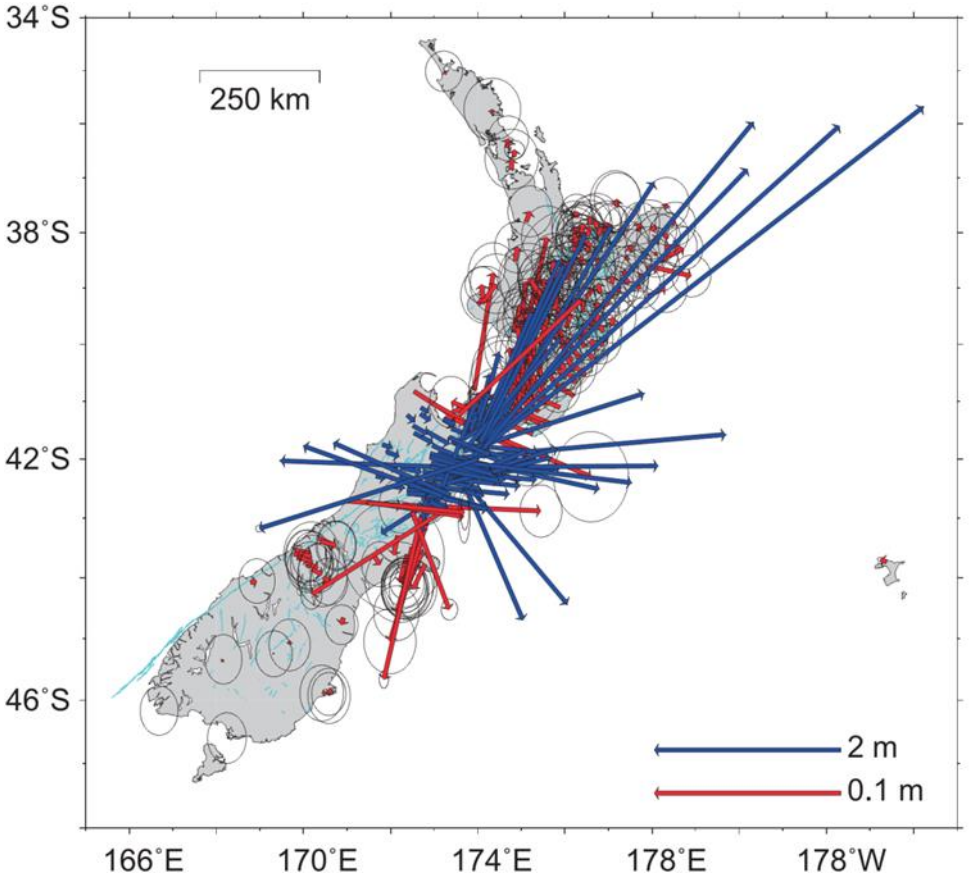


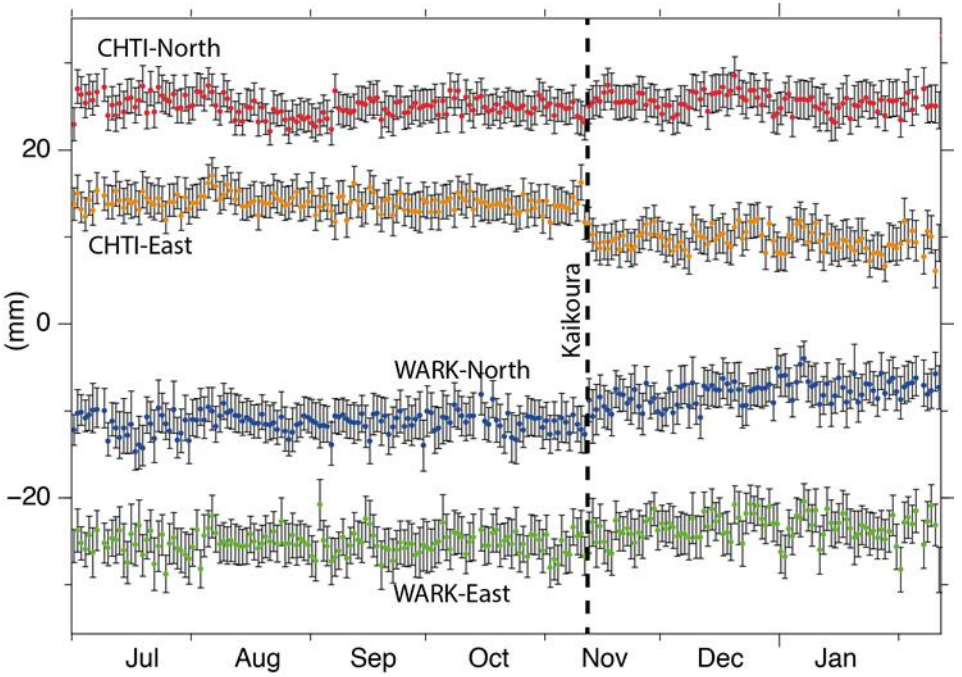
Courtesy Ian Hamling – GNS Science

Seismicity


Magnitude 4.0-5.0
Magnitude 5.0-6.0
Magnitude 6.0-7.0
Magnitude 7.8
0
90
km
Cape Farewell
Farewell Spit
GOLDEN BAY
Collingwood
Cape Stephens
D'URVILLE ISLAND
TASMAN BAY
French Pass
Motueka
NELSON
Richmond
Wakefield
Blenheim
WELLINGTON
COOK STRAIT
Kapiti I
Paraparaumu
Porirua
Lower Hutt
Cape Palliser
PALMERSTON NORTH
Levin
Otaki
Westport
Reefton
Waiau River
PEGASUS BAY
Waimakariri River
CHRISTCHURCH
Darfield
Rangiora
Kaiapoi
Amberley
Lyttelton
BANKS PENINSULA
HIKU

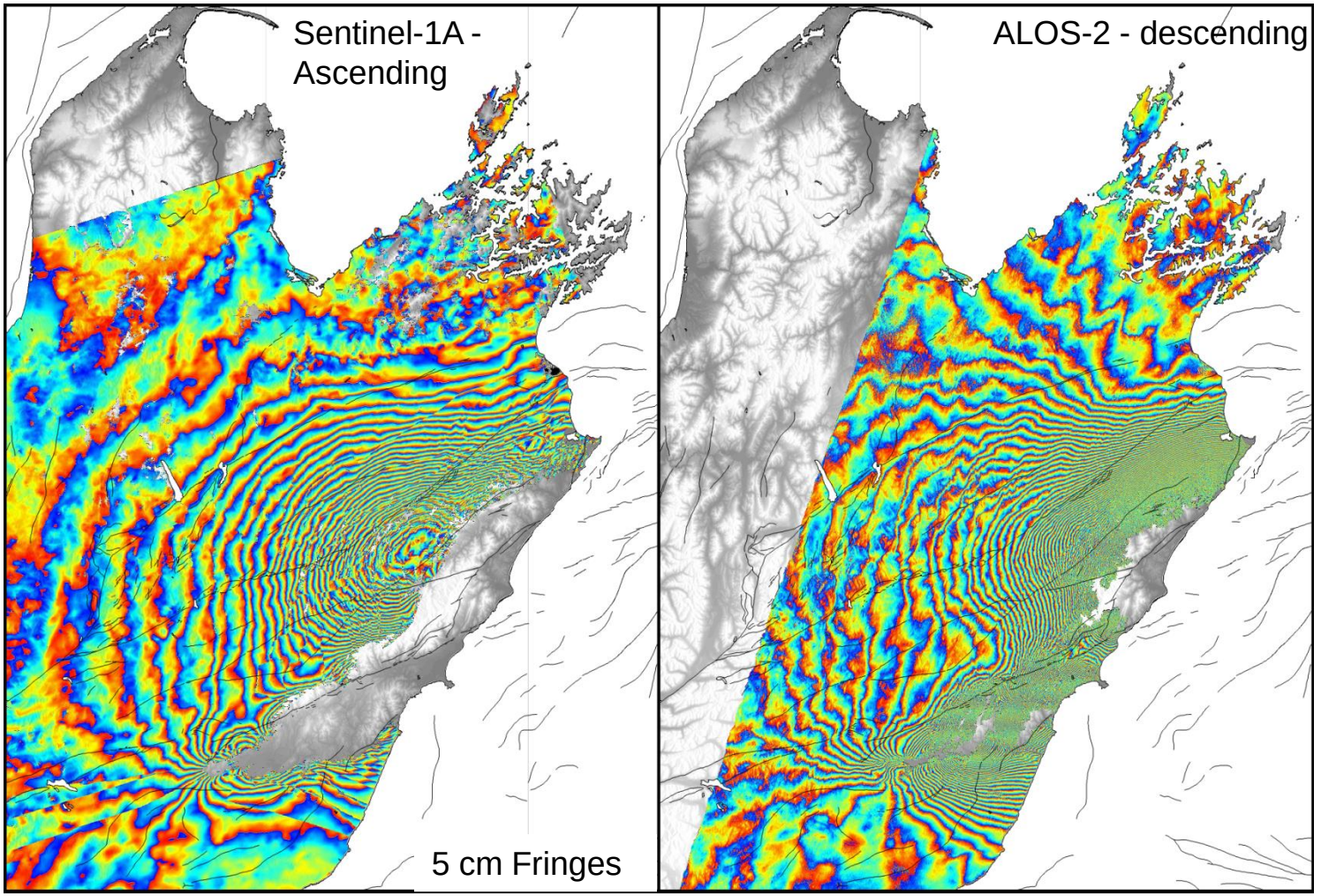
Observations - CORS





Courtesy Ian Hamling – GNS Science

Observations- InSAR

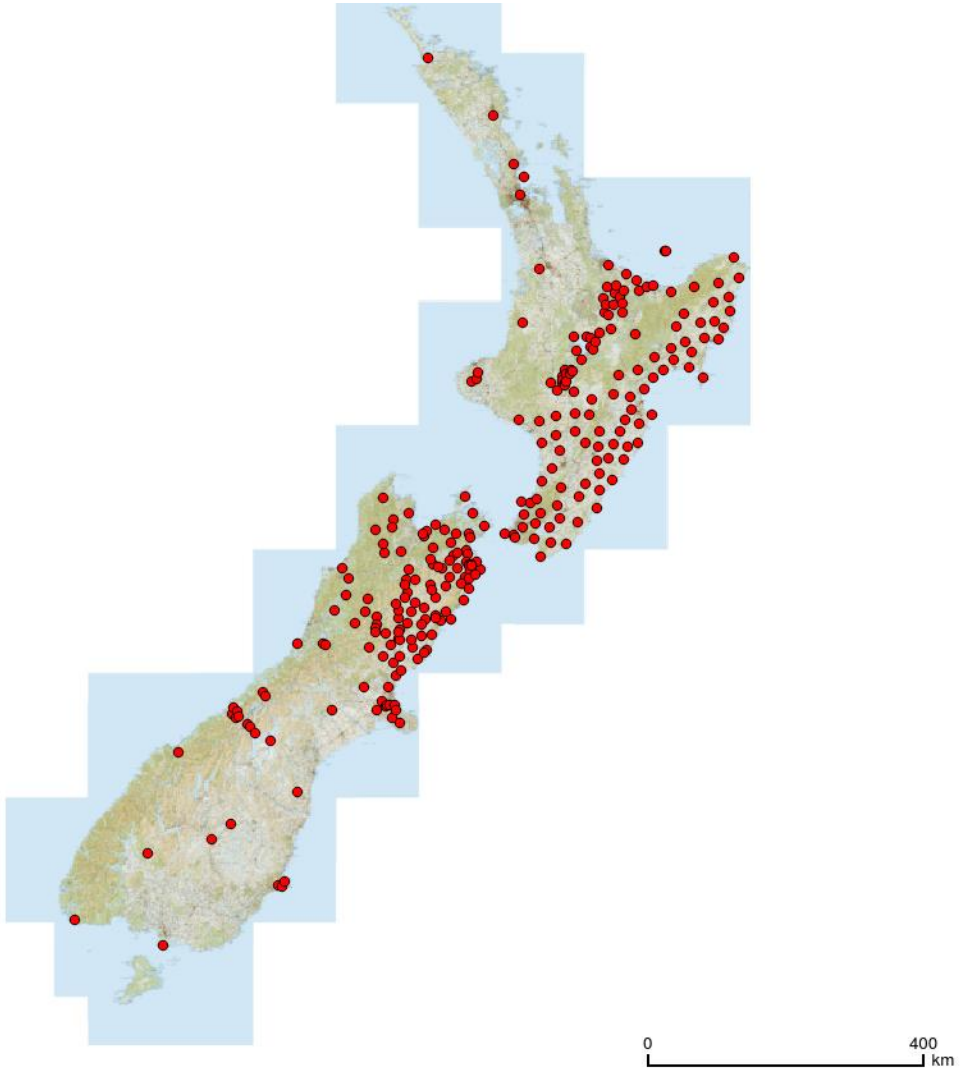


03/11/16 – 15/11/2016

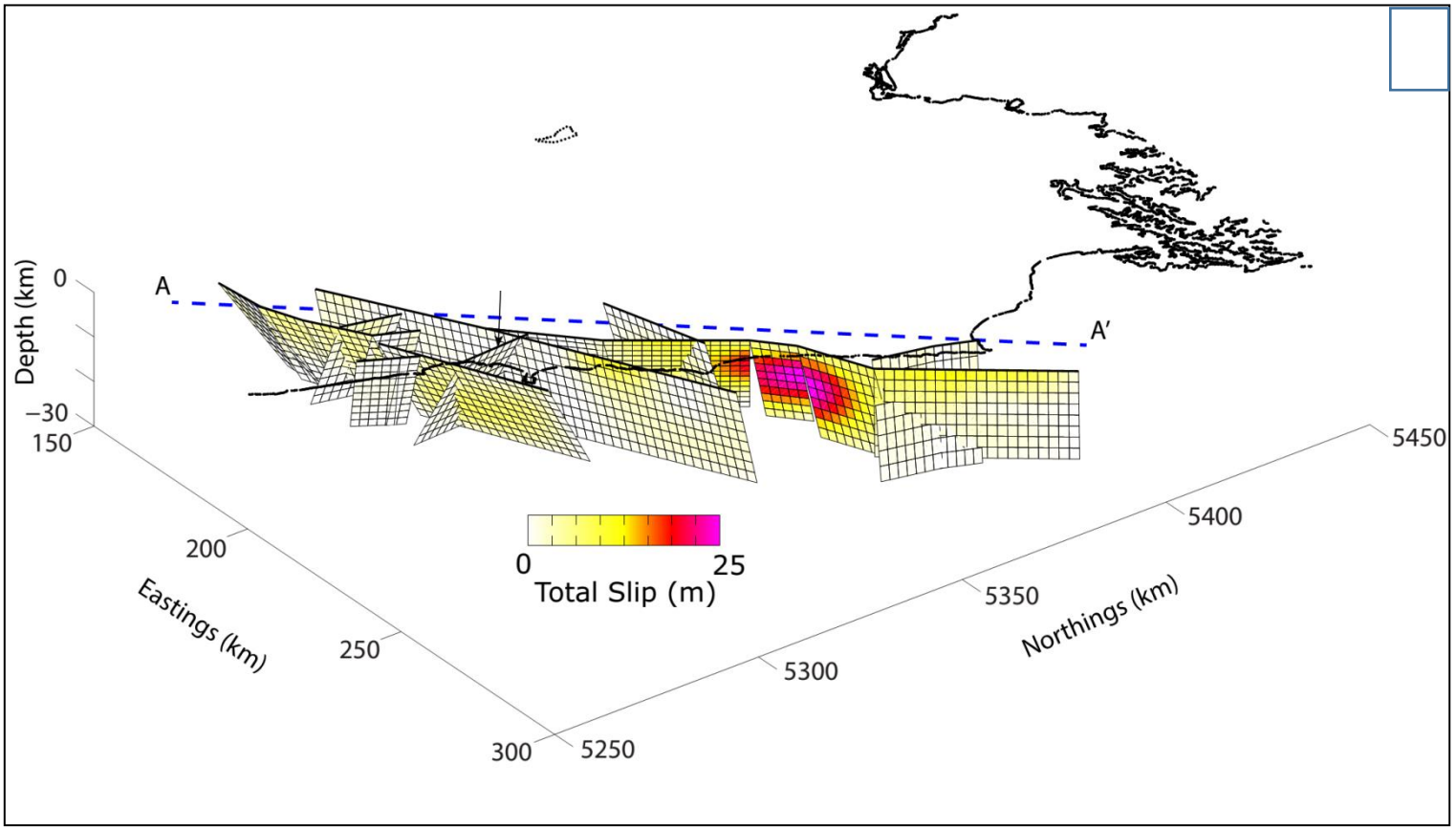
18/10/16 – 16/11/2016

Images provided by Ian Hamling – GNS Science

Observations- GNSS campaigns



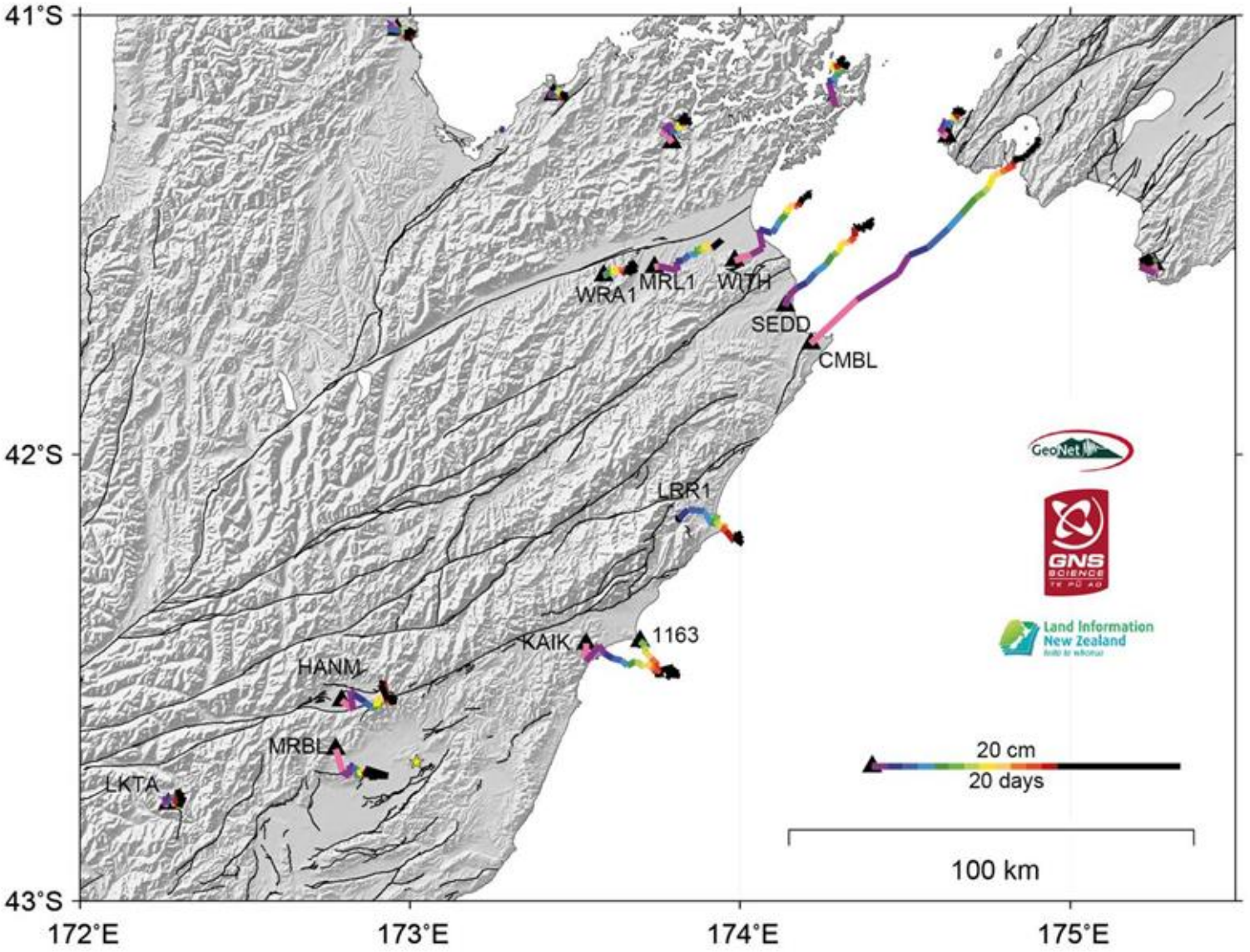
Geophysical model



Calculated using Okada (1985) formulae for surface displacement caused by slip on a rectangular fault.
Initial model based on seismology and geology
Inverted to fit GNSS, InSAR, and LiDAR data.

Courtesy Ian Hamling – GNS Science

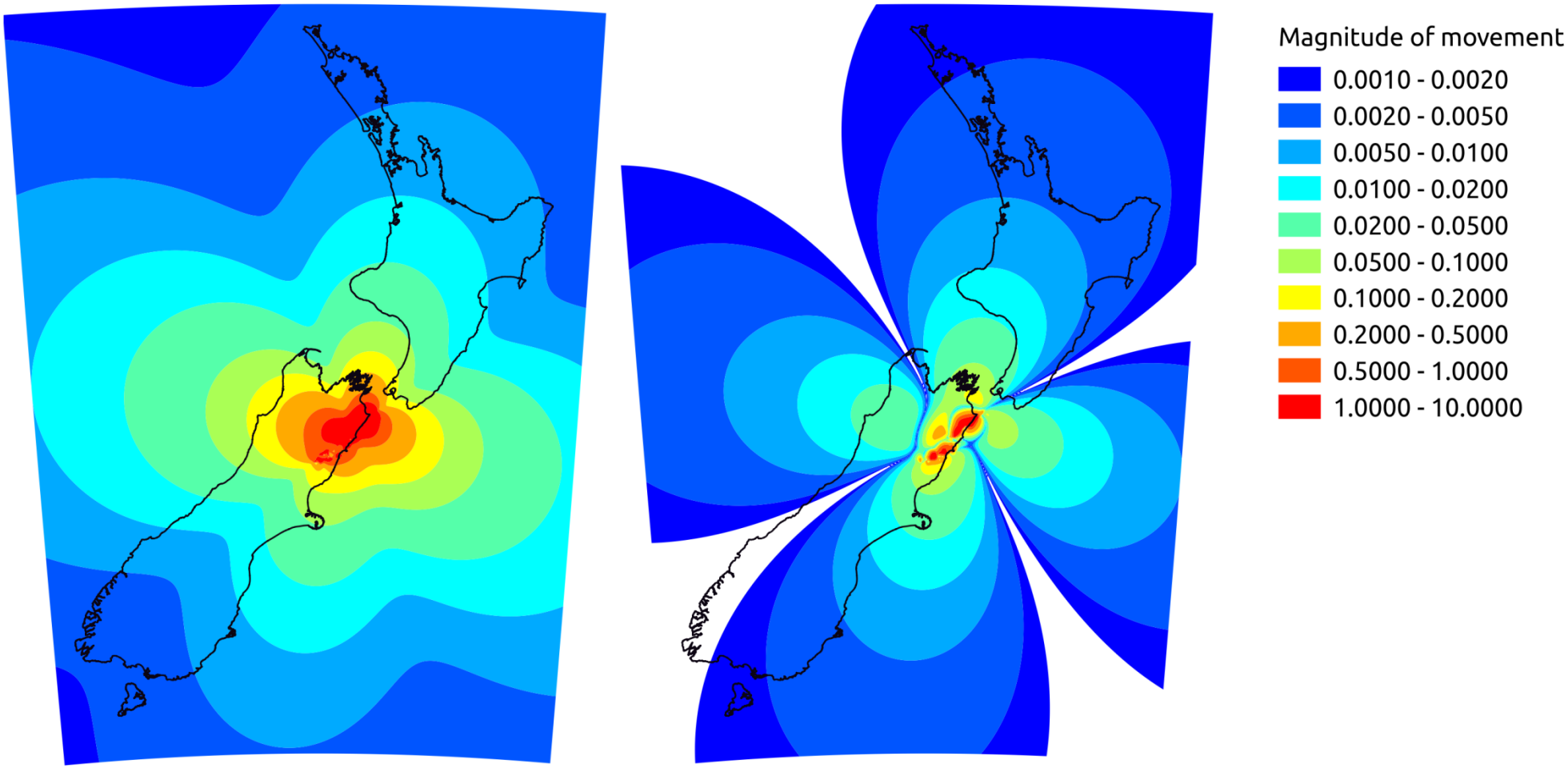
Post-seismic deformation



Derived surface displacements

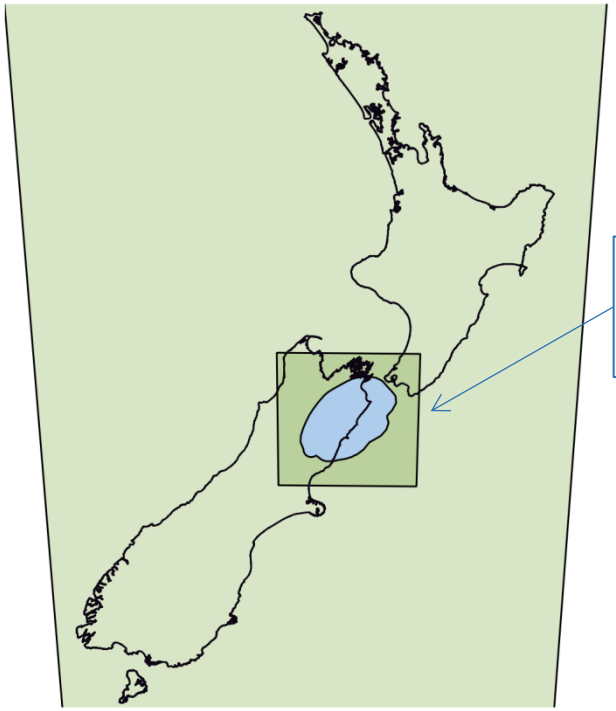
Horizontal movement

Vertical movement

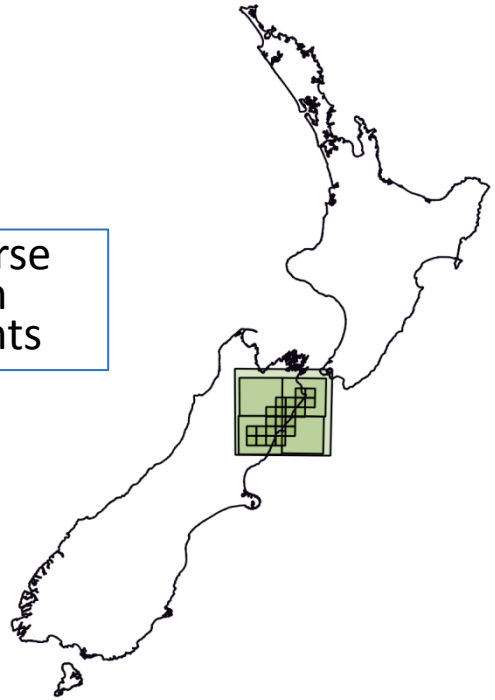


Gridded model

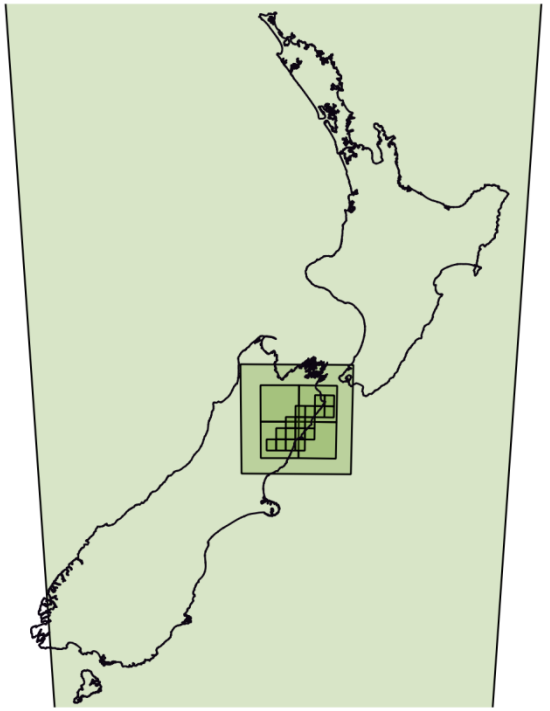
Forward horizontal patch



Reverse horizontal patch



Reverse vertical patch



Forward patch – changes deformation model but not coordinates

Reverse patch – changes coordinates and deformation model

Approximate grid spacing
Level 1: 13.4 km
Level 2: 3.4 km
Level 3: 840 m
Level 4: 210 m

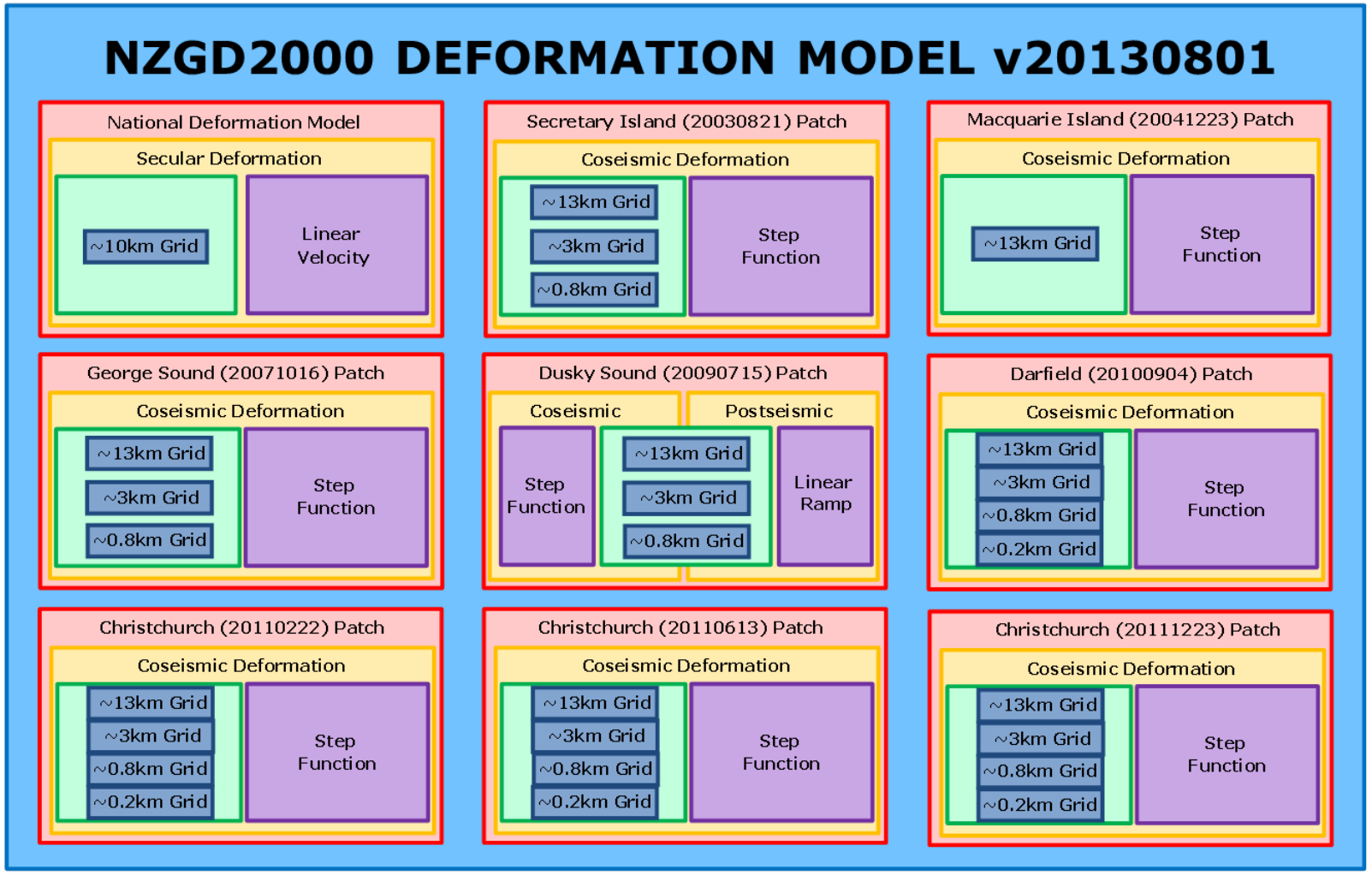
Publishing the model

Published in a number of formats

- Official model definition as CSV (comma separated value) files published on the LINZ website**
- NTv2 files for the horizontal reverse patch grids to facilitate updating GIS databases
- Incorporated into LINZ coordinate conversion products – online conversion and downloadable software (eg SNAP survey network adjustment software)
- Implemented into LINZ processes such as NZGD2000 coordinates calculated in PositioNZ-PP online GNSS post processing service
- Reverse patch coordinate updates applied to published LINZ data sets where appropriate (eg cadastral parcel data)

*** Not currently supported by 3rd party software*

NZGD2000


NZGD2000 DEFORMATION MODEL v20130801
National Deformation Model
Secular Deformation
~10km Grid
Linear Velocity
Secretary Island (20030821) Patch
Coseismic Deformation
~13km Grid
~3km Grid
~0.8km Grid
Step Function
Macquarie Island (20041223) Patch
Coseismic Deformation
~13km Grid
Step Function
George Sound (20071016) Patch
Coseismic Deformation
~13km Grid
~3km Grid
~0.8km Grid
Step Function
Dusky Sound (20090715) Patch
Coseismic
Step Function
Postseismic
~13km Grid
~3km Grid
~0.8km Grid
Linear Ramp
Darfield (20100904) Patch
Coseismic Deformation
~13km Grid
~3km Grid
~0.8km Grid
~0.2km Grid
Step Function
Christchurch (20110222) Patch
Coseismic Deformation
~13km Grid
~3km Grid
~0.8km Grid
~0.2km Grid
Step Function
Christchurch (20110613) Patch
Coseismic Deformation
~13km Grid
~3km Grid
~0.8km Grid
~0.2km Grid
Step Function
Christchurch (20111223) Patch
Coseismic Deformation
~13km Grid
~3km Grid
~0.8km Grid
~0.2km Grid
Step Function

Supporting post-eq surveys

Online support

Online support covering:

- Post-earthquake control survey methodologies
- How to reference coordinates
- Land movement maps

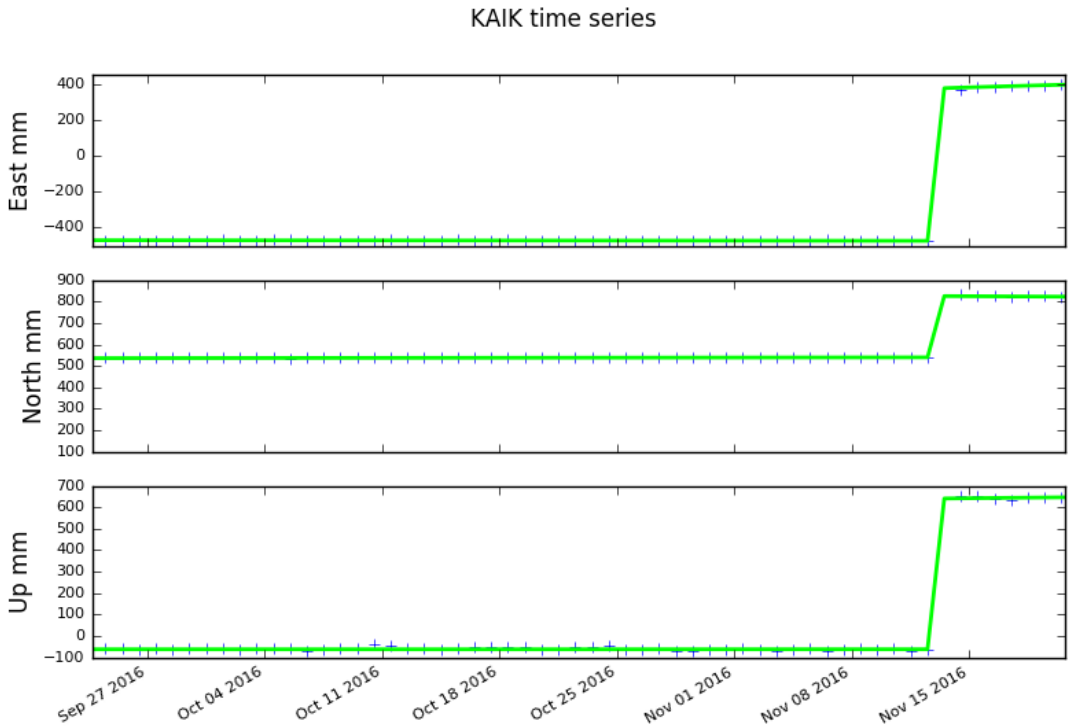
Provide direct support for survey profession in analysing survey data and providing “authoritative” reference coordinates.

East and north accuracy (95% confidence level) (m)		Height accuracy (95% confidence level) (m)		Minimum distance between control marks (m)	Minimum time for each occupation (2 occupations for each mark required) (hours)	Order	
Local (vector between control marks)	*Network (coordinate in terms of PositioNZ stations)*	*Local (height change between control marks)*	*Network (height in terms of PositioNZ stations)*			*NZGD2000*	*NZVD2016*
0.010	0.005	0.015	0.010	4000	16	3	1V
0.010	0.005	0.015	0.010	1500	16	4	2V
0.020	0.015	0.030	0.020	3000	4	4	2V
0.020	0.015	0.030	0.020	300	4	5	3V
0.030	0.020	0.050	0.040	700	3	5	3V
0.040	0.030	0.060	0.050	1500	2	5	3V

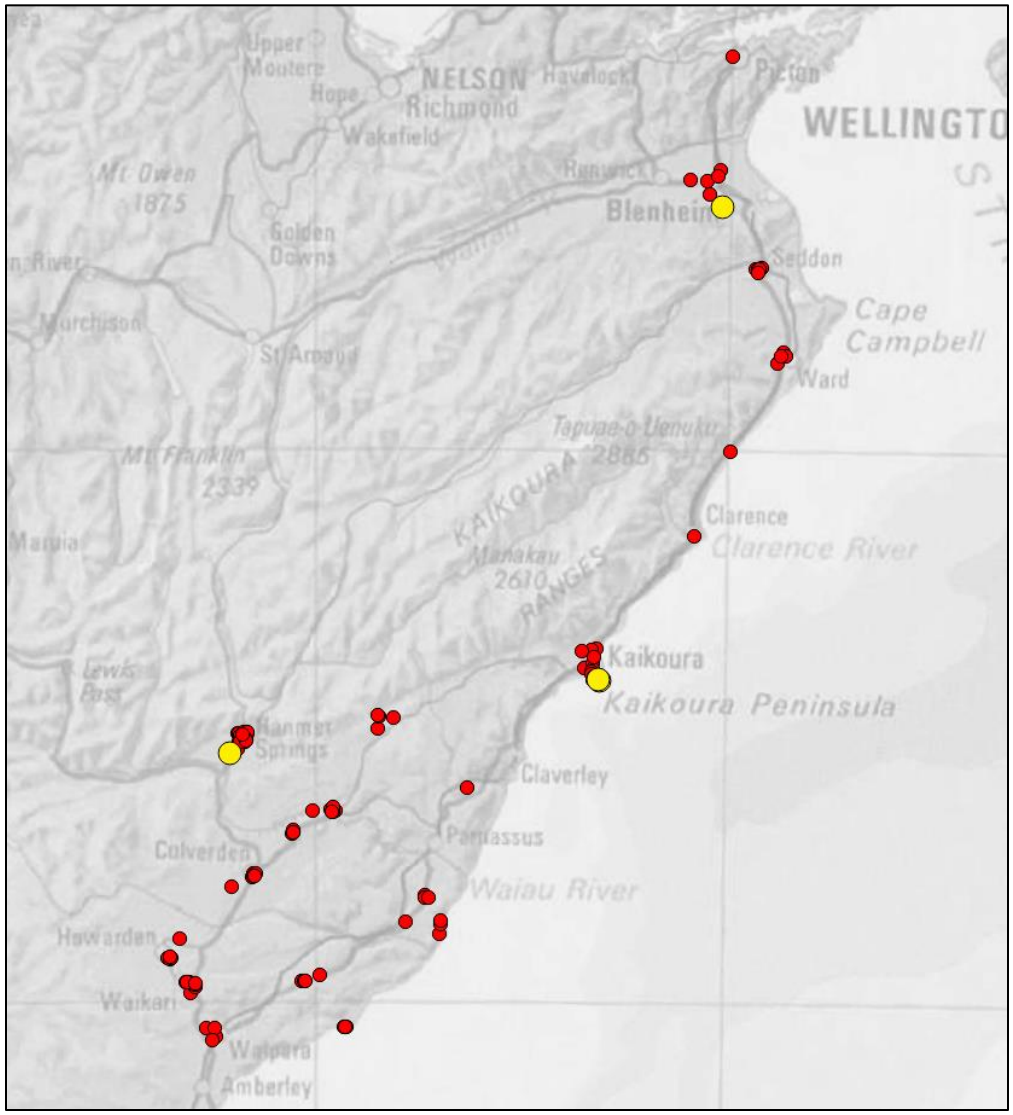
PositioNZ-PP update

PositioNZ-PP online GNSS post processing service

- Update station coordinate models defining reference coordinates of stations.
- Allows surveyors to generate new control marks



Post earthquake urban control

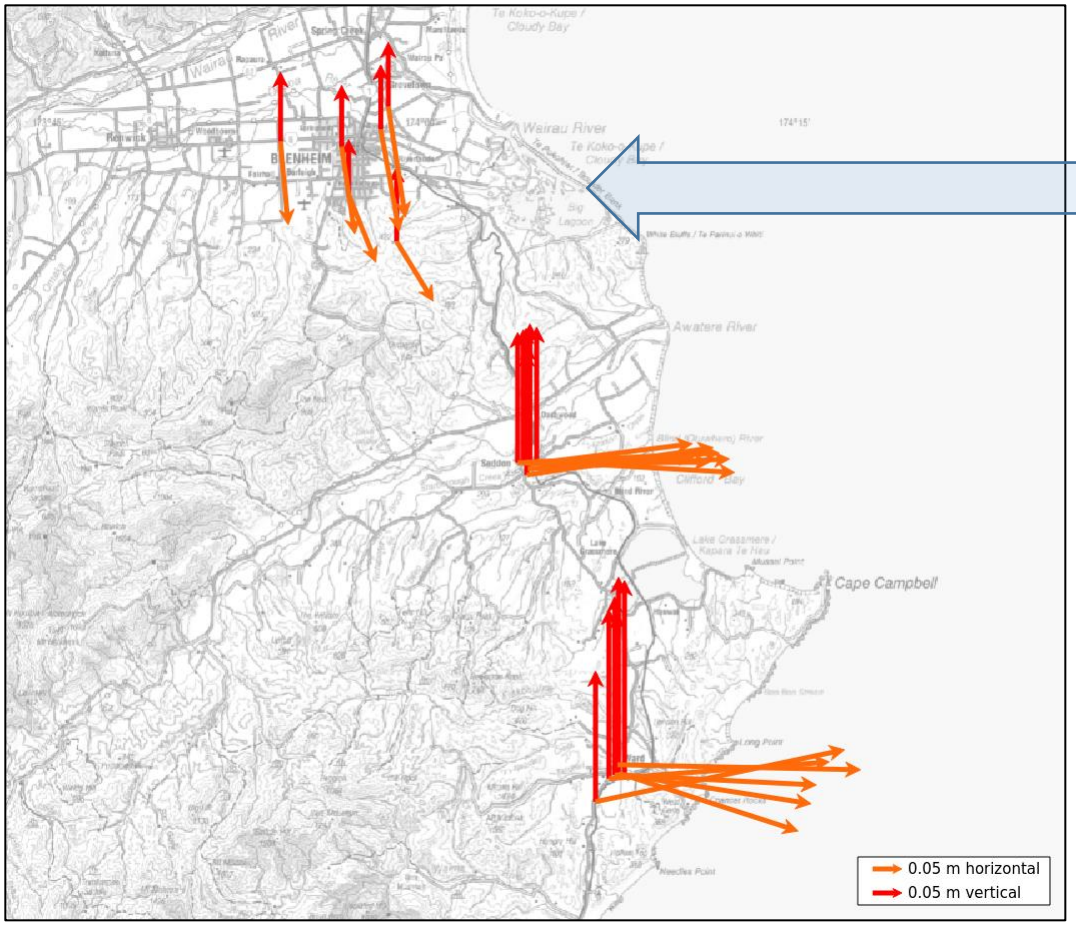


Urban control surveyed within 1 month of earthquake

4-hour plus 1-hour GNSS occupations at base station in each locality (yellow)

Other marks surveyed with RTK

Post earthquake urban control

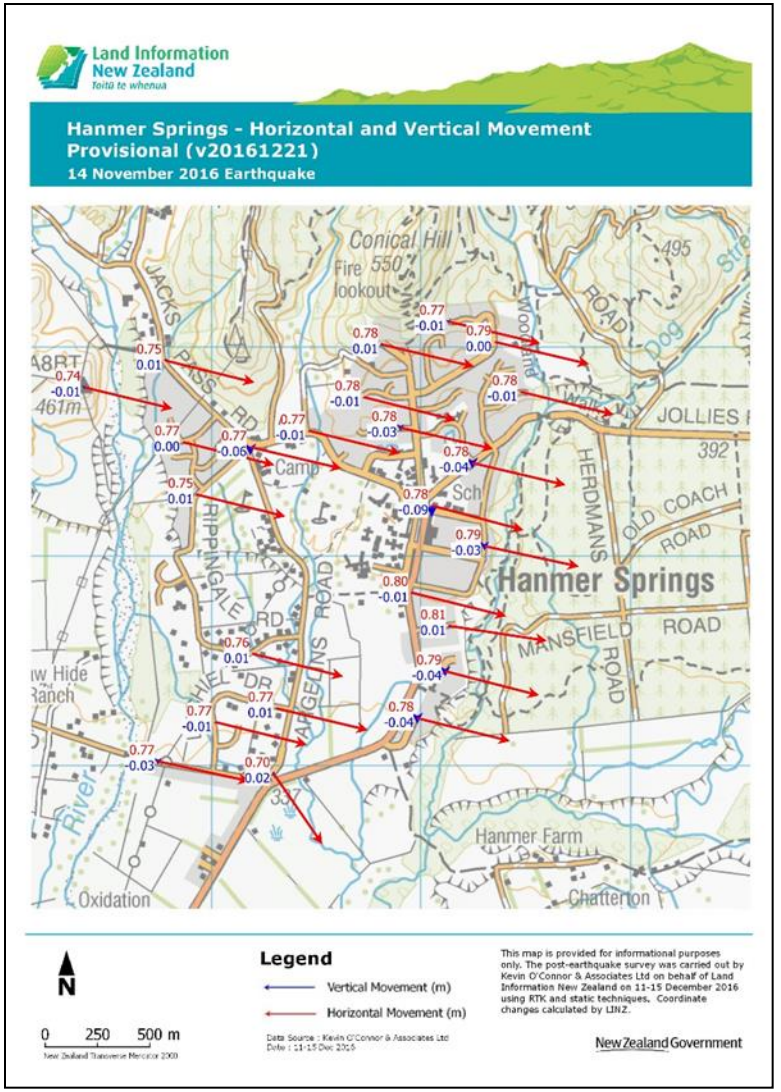


Code	dE	dN	dH
ACYP	0.175	0.586	0.027
APKE	0.187	0.626	0.033
BE0G	0.173	0.563	0.046
APCA	0.185	0.633	0.033
B8RP	0.235	0.744	0.037
WITH	0.285	0.898	0.092

Post earthquake urban control

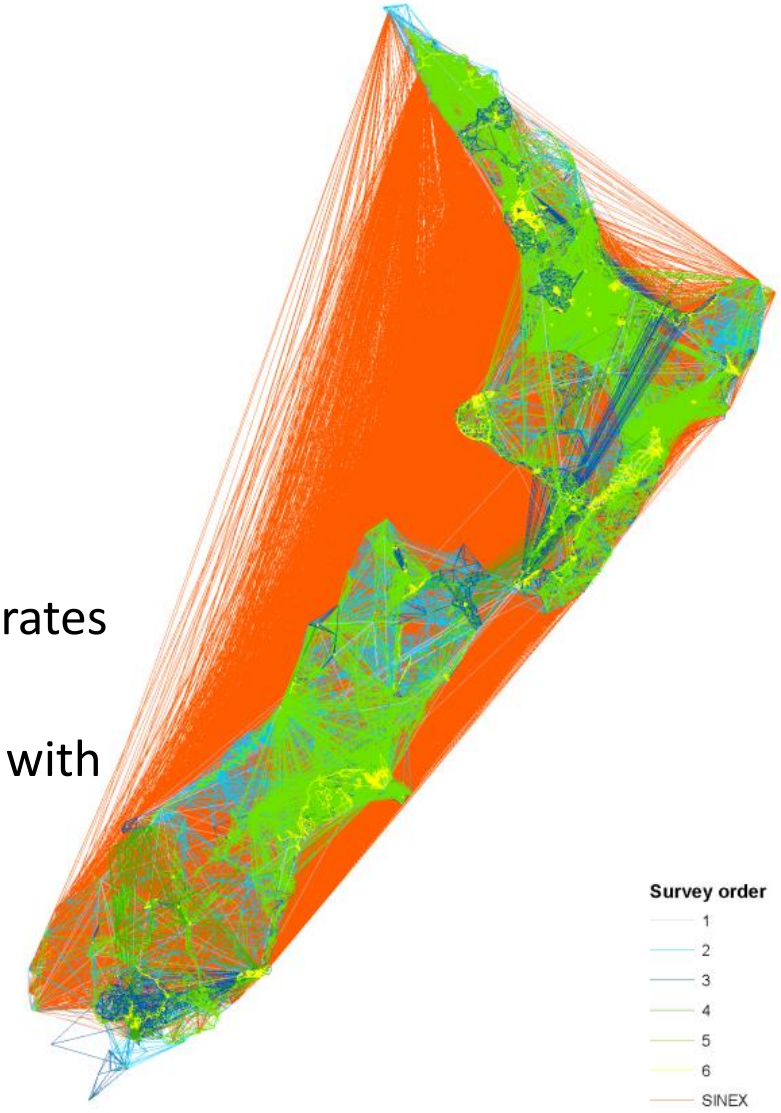
New control coordinates published using online “LINZ data service (http://data.linz.govt.nz)

Also published as PDF maps for each town.



National Geodetic Adjustment

- > 100,000 marks
- Includes:
  - All GPS/GNSS data since 1990s
  - Terrestrial geodetic observations
  - Levelling observations
- Using LINZ SNAP software which incorporates deformation model into adjustment
- Entire network updated to be consistent with new deformation model



Question?