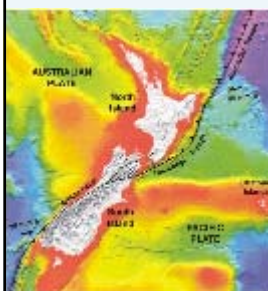# The Application of a Localised Deformation Model After an Earthquake

R. Winefield, C. Crook, and J. Beavan
Land Information New Zealand & GNS Science
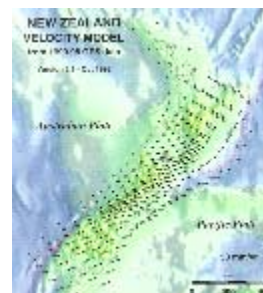**Wellington, New Zealand**

Presentation to:
XXIV FIG International Congress 2010
Sydney, Australia,
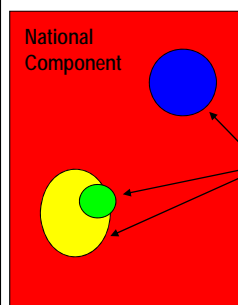11-16 April 2010

Implementation of NZGD2000

- **Straddles the Pacific/Australian tectonic plate boundary**
- **Approximately 5cm/yr movement**

- **NZGD2000 (ref epoch 1 Jan 2000)**
- **Semi-dynamic datum**
- **Horizontal coordinates stored at reference epoch**
- **Incorporates deformation model**
  - enables propagation of coordinates and observations between epochs

NZGD2000 Deformation Model

Toitu te
Land whenua
Information
New Zealand

- Defined to include a national component and localised "patches"
- National model can be updated periodically
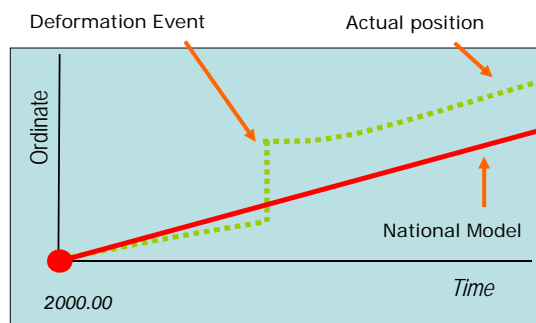- Local patches can be added as required

National Component

Patches

- Coordinates of a point can be calculated to any specific time by applying:

Reference coordinates + Deformation model
(including patches)

Patch Options

Toitu te
Land whenua
Information
New Zealand

- **Forward patch**
  - Reference coordinates unchanged
  - Model accounts for deformation
- **Reverse patch**
  - Reference coordinates change
  - Model reverses the coordinate change

- **Hybrid patch**
  - Some deformation is account for by changing coordinates
  - Some deformation is account for by applying a model

Deformation Event   Actual position

Ordinate
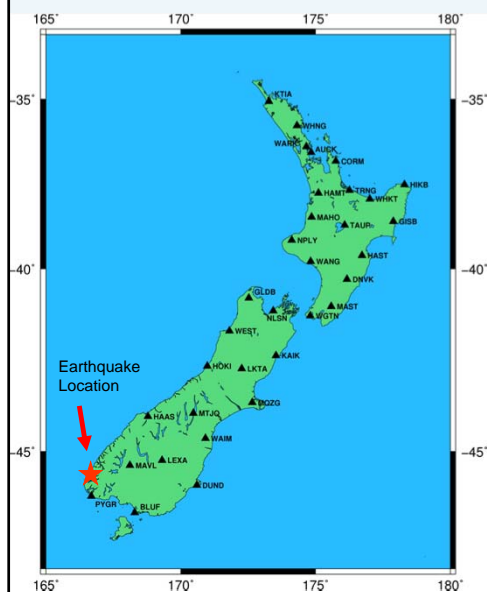
National Model

2000.00   Time

Points to Consider

- User requirements
  - Reference coordinates sufficient
- GIS software capabilities
- Expectations of users
  - Extents of deformation events
  - Hybrid patch example
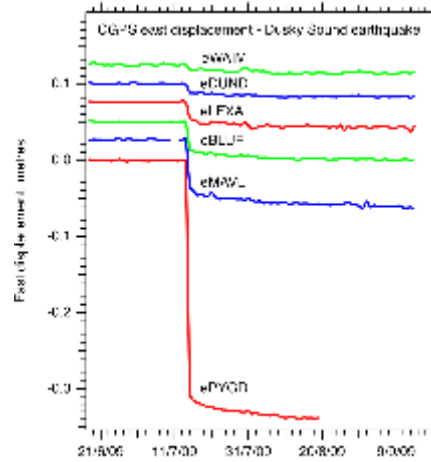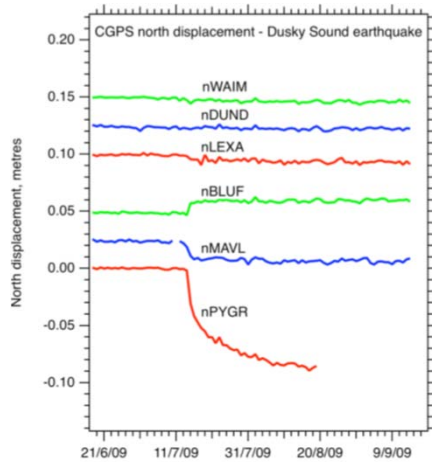- When to release a patch
- How to construct a patch

Fiordland Earthquake 2009

Earthquake Location

- Dusky Sound
- 15 July 2009
  - After shocks continued for months
- Magnitude 7.7
  - Largest earthquake in New Zealand since 1931
  - Most significant deformation event since NZGD2000
- Sparsely populated area
  - No fatalities
  - Little economic damage
- Effects detected by PositioNZ
  - NZ CORS network

Displacement at CORS Stations

Puysegur Point (300 mm) **Mavora Lakes (60 mm)**

Bluff (30 mm), **Alexandra (20 mm)**

Dunedin (10 mm) **Waimate (10 mm)**

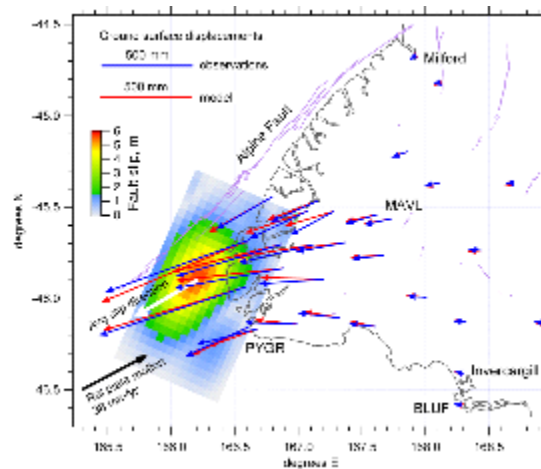

Displacement Model

- GPS Campaign
  - 27 Marks
  - 48 hour occupation
- L-band InSAR
- PositioNZ

Blue: observed displacements

Red: modelled displacements

Depth of main slip patch is 10-25 km.

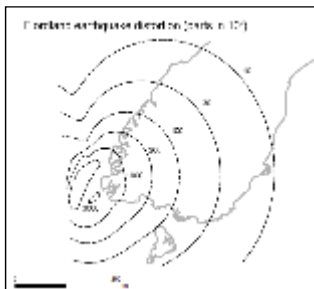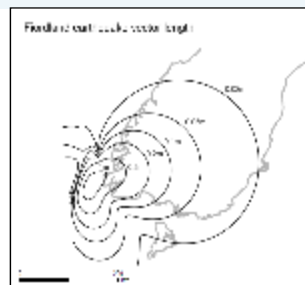White arrow shows average slip direction

Patch Implementation

From the impacts of the event we need to decide:

- How much deformation applied as a reverse patch?
- How much deformation applied as a forward patch?
  - Is a patch required?
- How often should patches be generated?
  - Post-seismic deformation?
- How will the patch be constructed?
  - What density of points to use?
  - What spatial extents shall the patch cover?
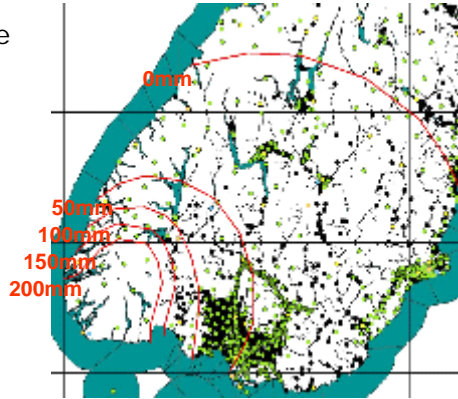
Apportioning Deformation

- Network Accuracy
  - Horizontal Component of the deformation vector
  - ~1m in southwest Fiordland
    (direction of National Deformation)
  - >0.15m 95% accuracy requirement LINZ
  - Total Deformation post NZGD2000 ~1m

- Relative Local Accuracy
  - LINZ accuracy requirement on the surface ~5000 in 10^8
  - Model Fault plane 5km deep
  - Most deformation offshore
  - Not significantly compromised
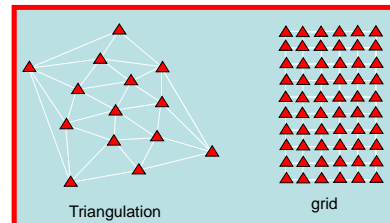   - **No advantage changing reference coordinates**

Patch Extents

- Patch must extend to area which exceed requirements
- How much can a point move without compromising accuracy requirements?
  - DMN mark 0.1m at 95% C.I.
  - Surveyed to 0.08m 85% C.I.
  - Allowed 0.037m
    - Still 95% with .1m
  - Required accuracy 0.02 + 4pp 10^8
- Local Accuracy requires 450km from Epicentre

0mm
50mm
100mm
150mm
200mm

Resolution of the Patch Model

Patch deformation is deformation at control points

Points between control are calculated by linear interpolation

Required accuracy 0.02 + 4pp 10^8

Finest spacing required ~300m

- Grid
  - 480km x 480km = approx 2,500,000 points
- Triangulation
  - Approximately 47,000 points
- Multiple grid
  - Several Grids at multiple resolutions
  - Fine grid near Epicentre/ Coarser grid for far extents
  - Approximately 150,000 points

Triangulation   grid

Conclusion

- Fiordland ~7.7 earthquake most significant deformation event since NZGD2000 was introduced
- Horizontal displacements up to 1m
  - Local accuracy requirements are not compromised for most users
  - Absolute accuracy standards are compromised
    - Not greater than tolerated errors in reference coordinates currently
- This deformation event should be included as a "forward" patch
  - Reference coordinates will not be changed
  - Few effects for users of GIS data sets
- Proposal: that a forward patch, comprised of several grid models to be implemented