Modelling Time Dependent Transient Deformation in New Zealand

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FIG Working Week 2016

CHRISTCHURCH, NEW ZEALAND 2–6 MAY 2016

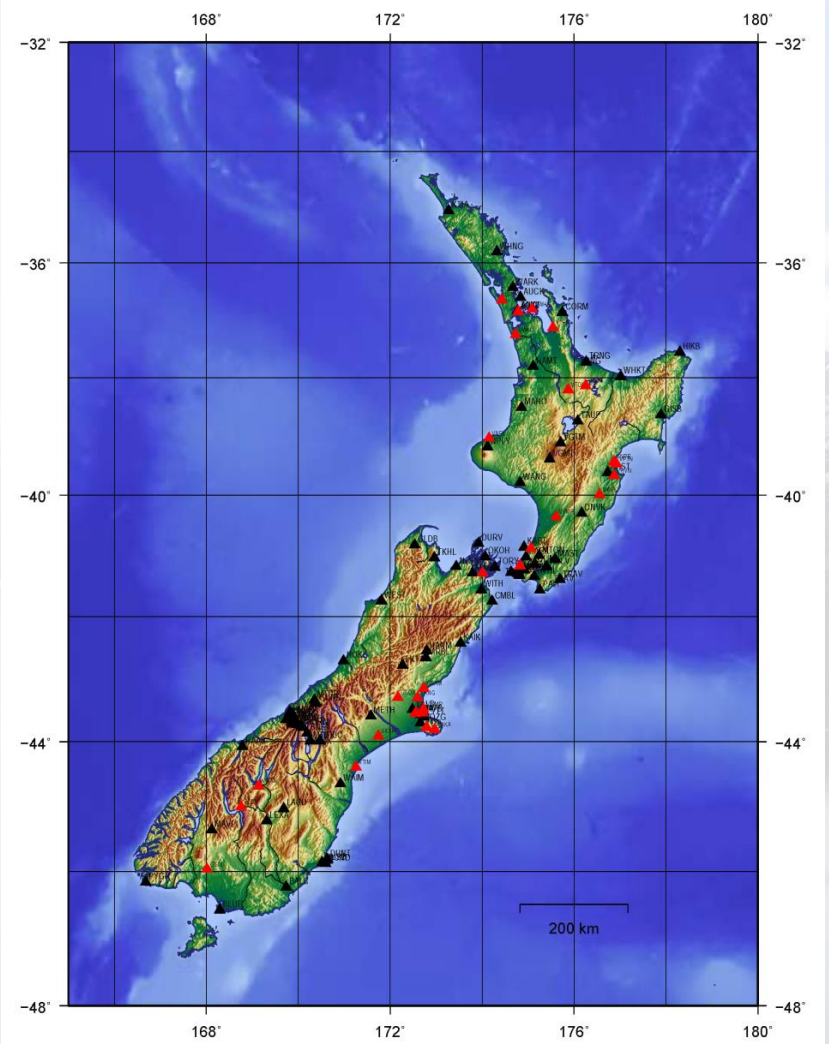
Recovery from disaster

Organised by FIG NZIS

Platinum Partners Trimble esri

Diamond Partner Land Information New Zealand Toitū te whenua

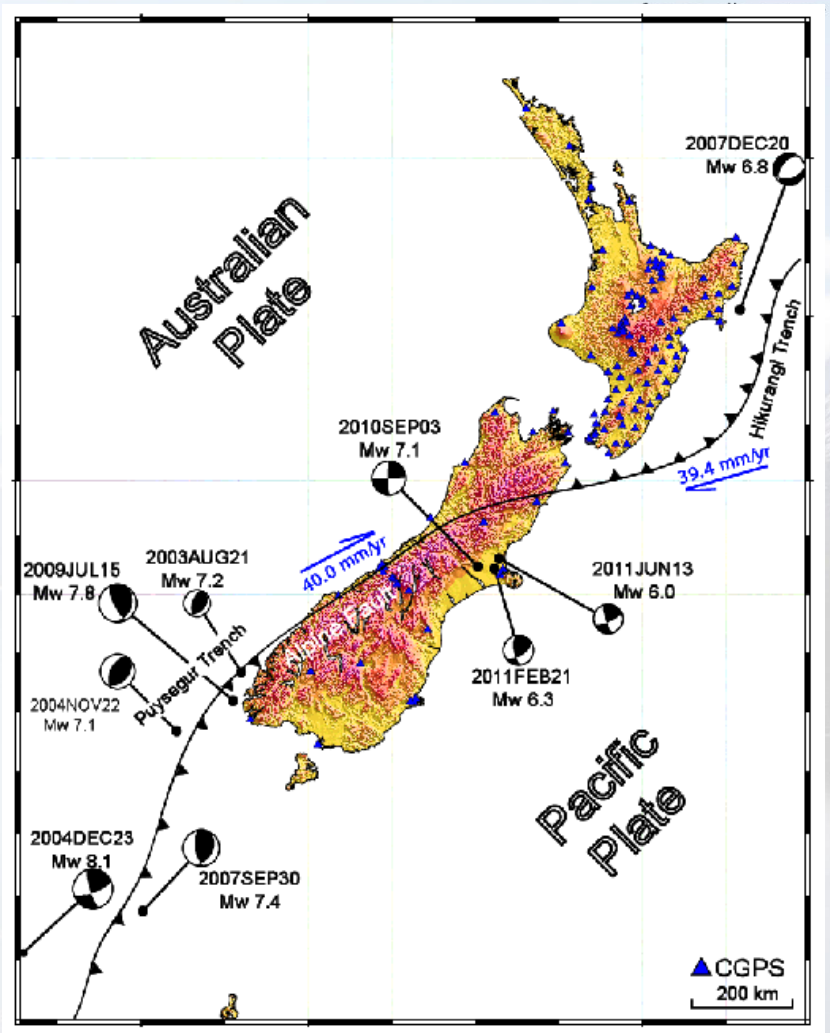
- **Motivation**
  - Surveying positioning applications are transferred to the national datum at a specific reference epoch
    - e.g. NZGD2000, epoch 2000.0
- **Positioning Applications**
  - Long baselines – PositionNZ-PP
  - Current epoch positioning – ITRF2008
    - PPP, PositioNZ-PP
  - Network RTK
- **Deformation**
  - Time dependent and transient



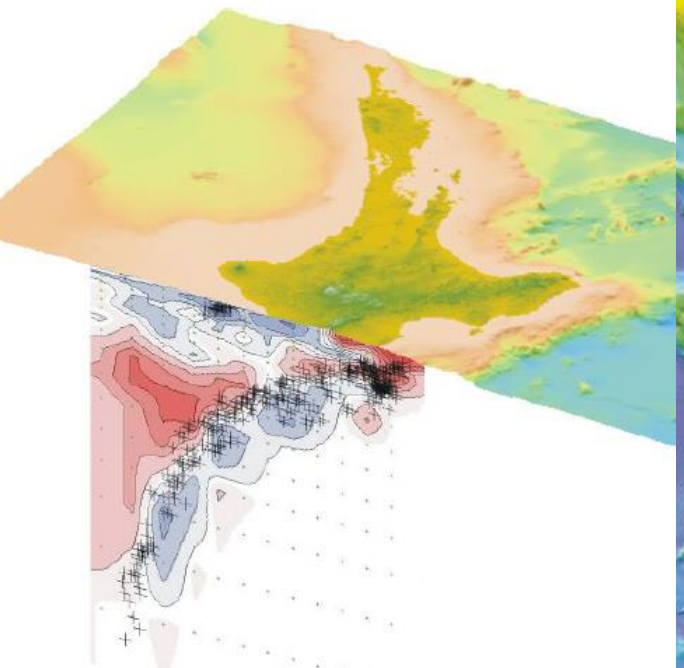
Earthquake Events

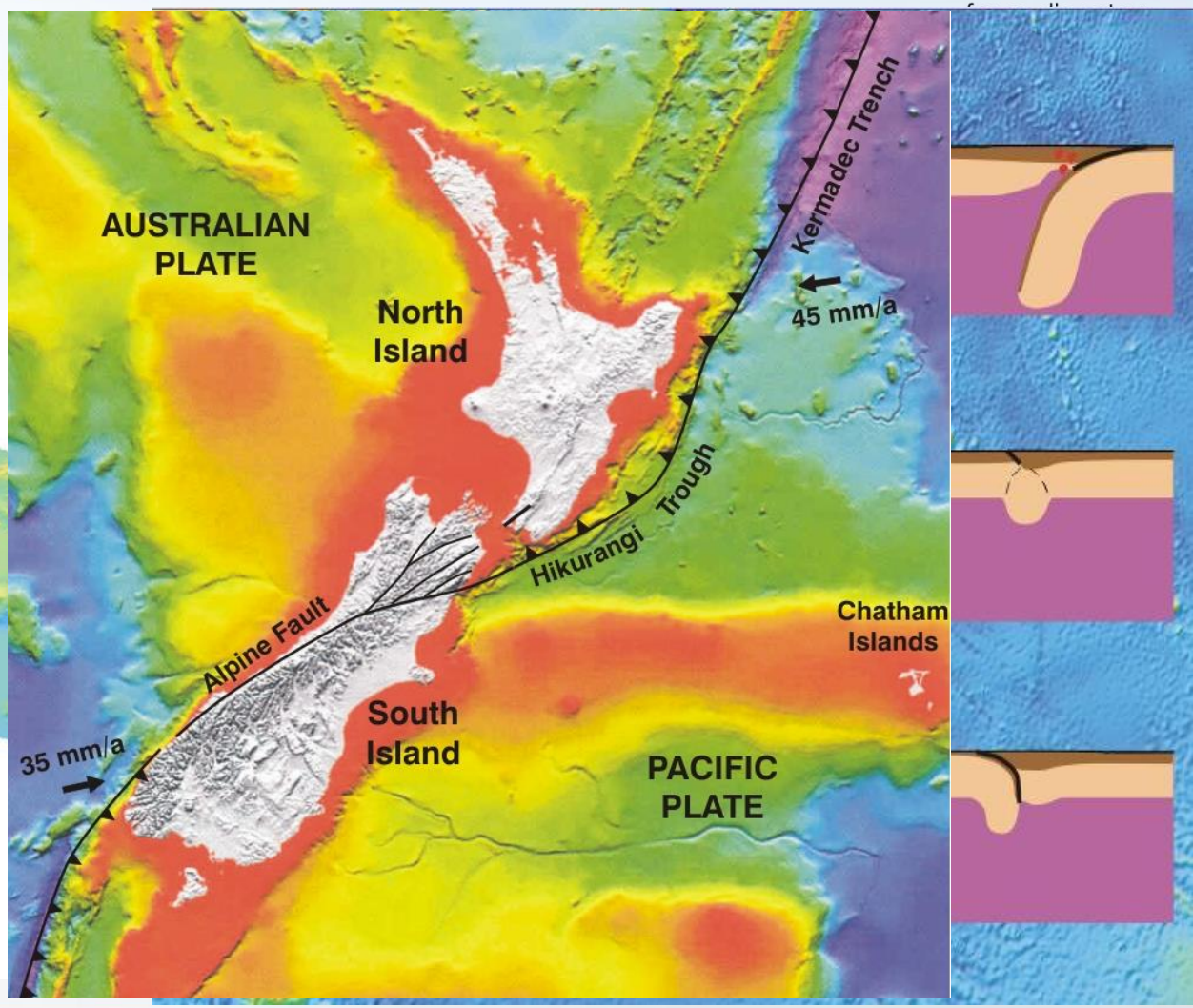
- 12 major events since 2003
- many cGNSS sites affected

Christchurch CBD post 2010-11



Tectonic Setting





Source: GNS Science

Centimetre Positioning Applications

Complex deformation affects centimetre positioning applications :

GNSS Positioning Engines

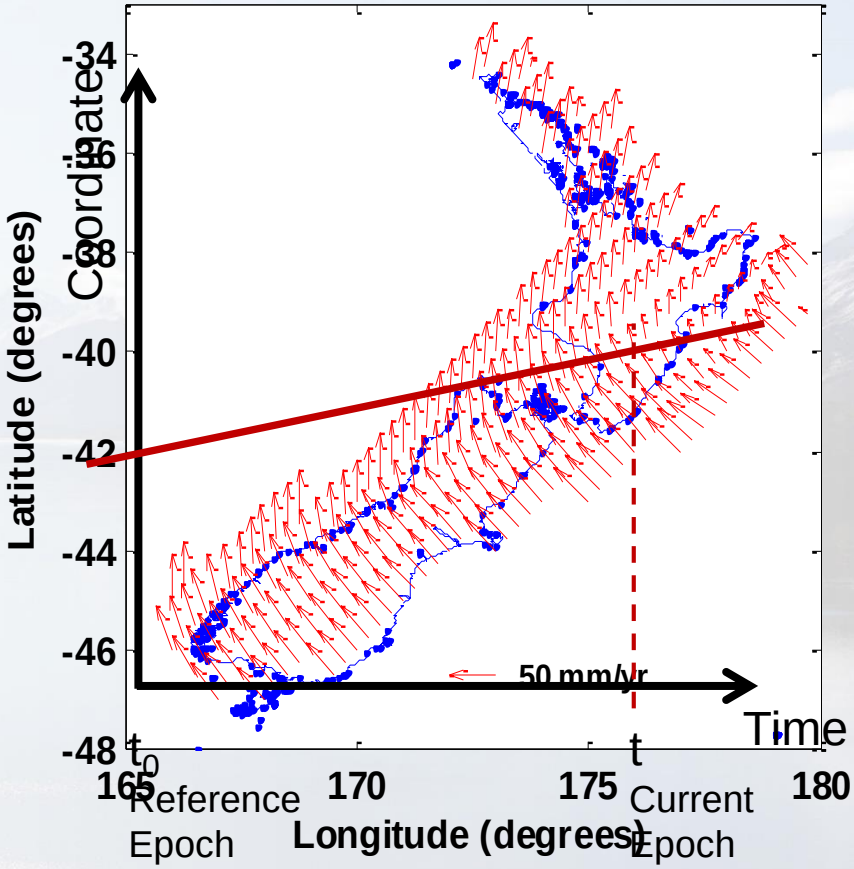
- Satellites in terms of ITRF2008
- User/Rover transformed to user's local datum

Network RTK

- Reference station coordinates in terms of ITRF2008
  - Secular velocity only :

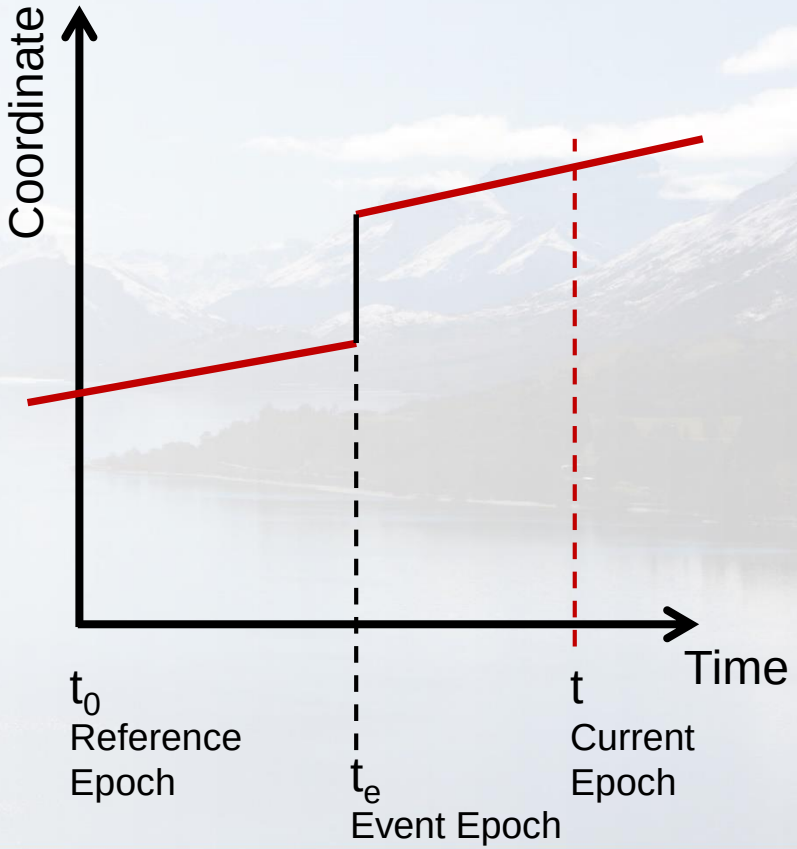
$$X(t) = X_0 + v_X(t - t_0)$$

- User/Rover transformed to user's local datum



How are geophysical processes with non-linear signatures such as seismic events dealt with?

- Coseismic offsets
  - Easy



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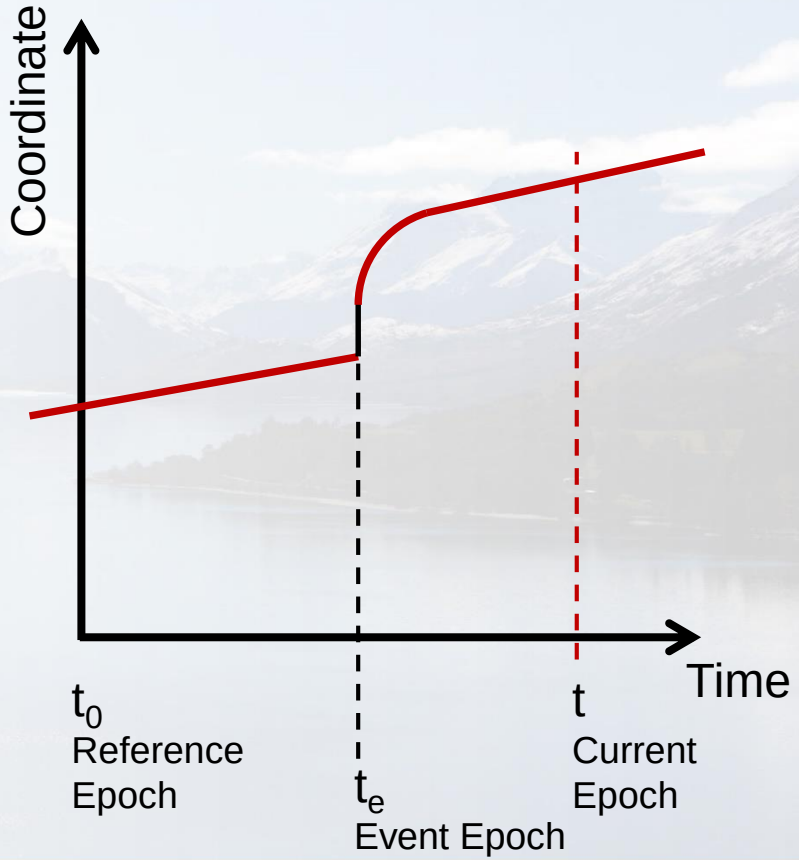
- Post-seismic relaxation
  - Harder
  - Requires measurements to determine amplitude of decay



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- Coseismic offsets
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- Post-seismic relaxation
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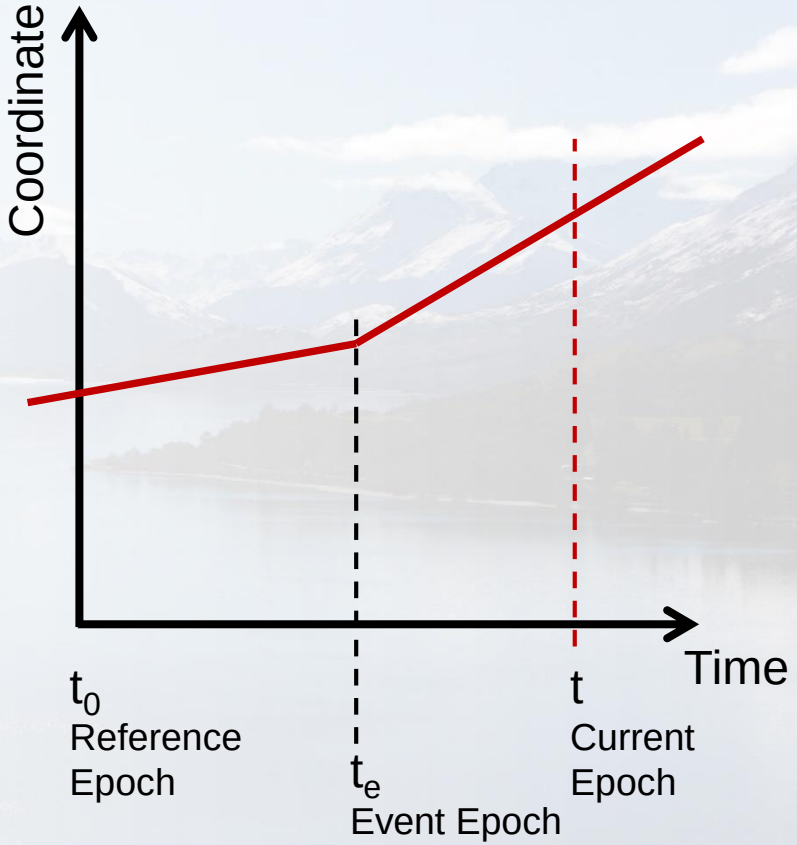
  - Requires time to determine amplitude of decay
- Transient velocities
  - Harder
  - Requires time to determine change in velocity



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- Coseismic offsets
  - Easy
- Post-seismic relaxation
  - Harder
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- Transient velocities
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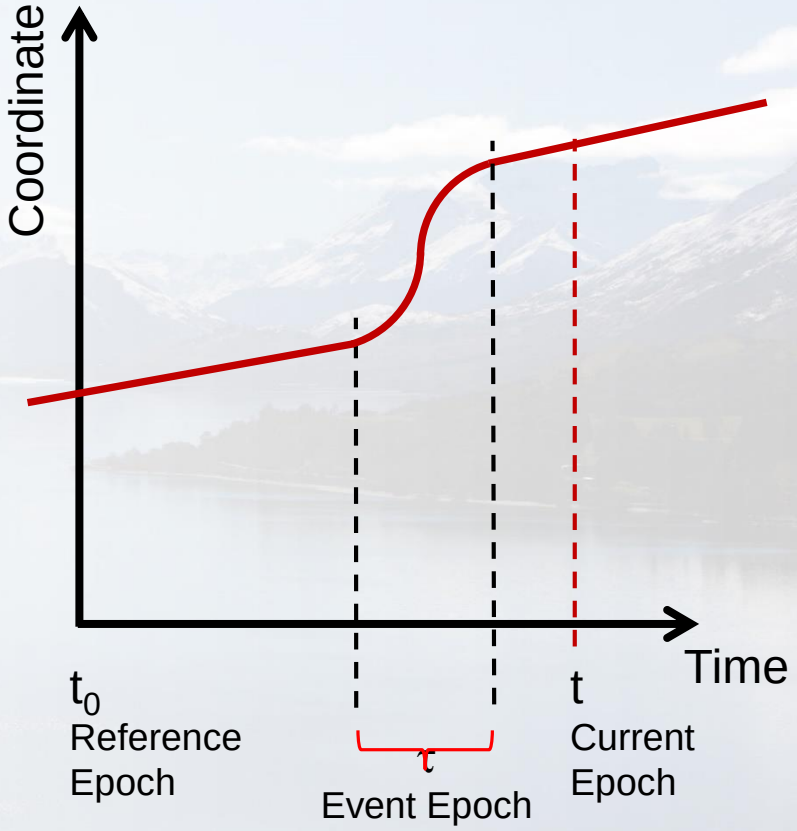
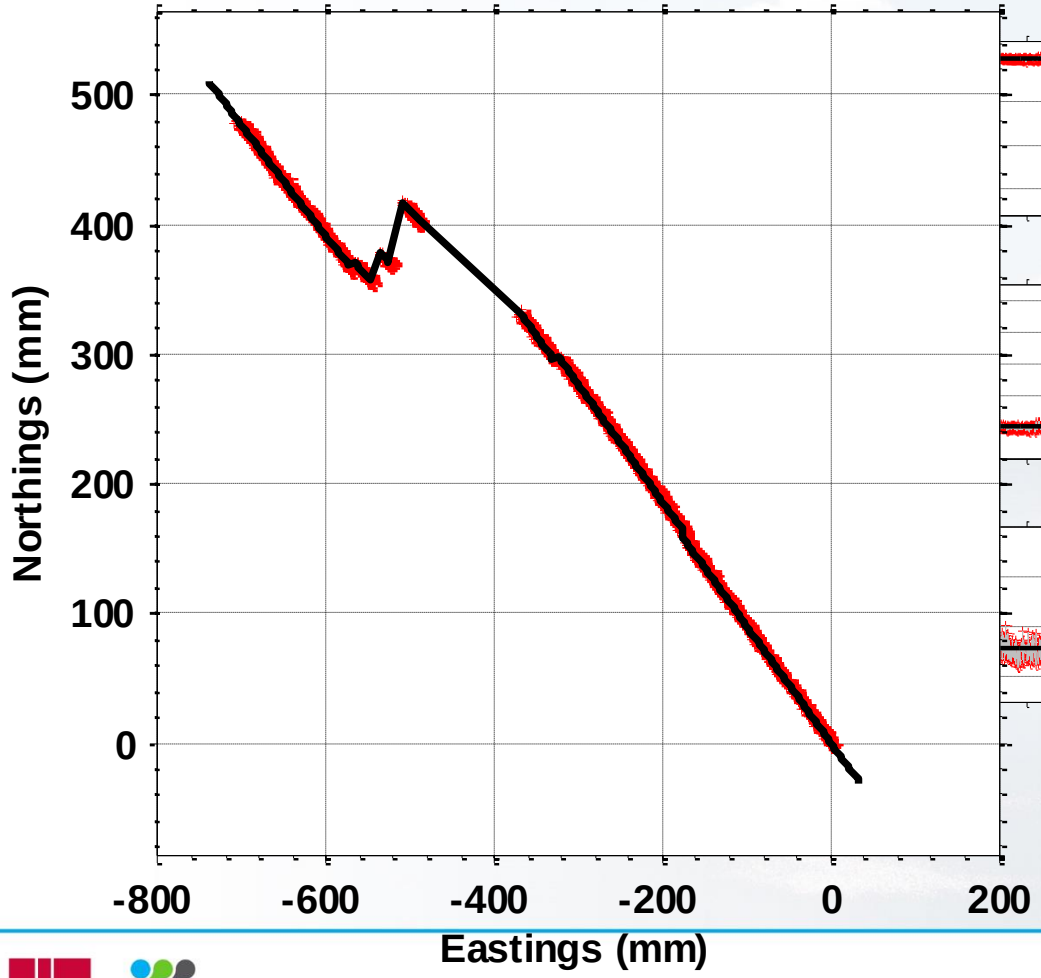
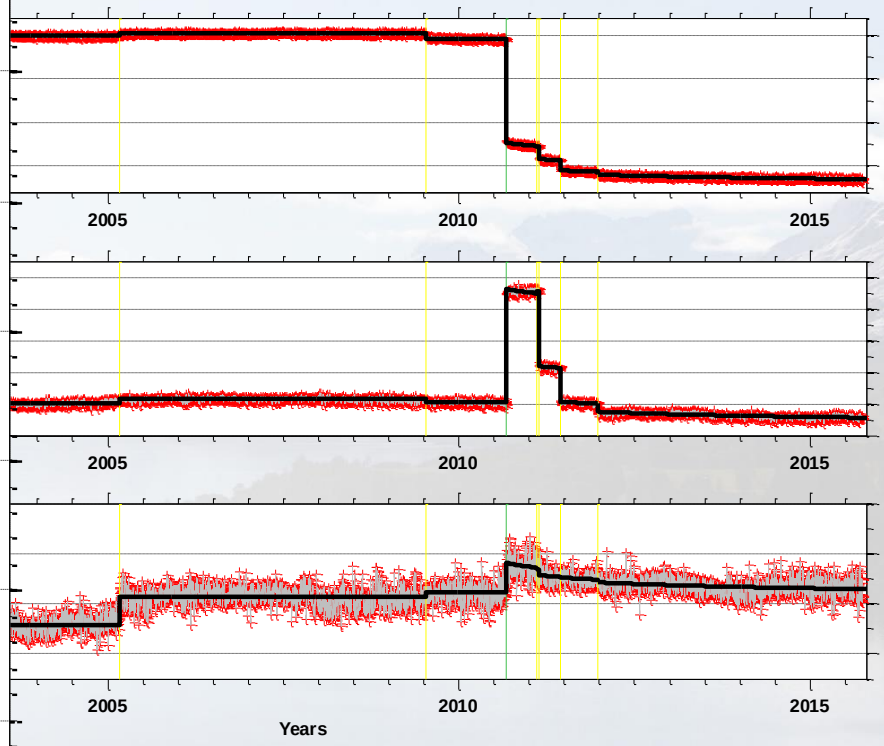
  - Requires time to determine change in velocity
- Slow slip events
  - Difficult
  - Events occur over days – weeks – months – years

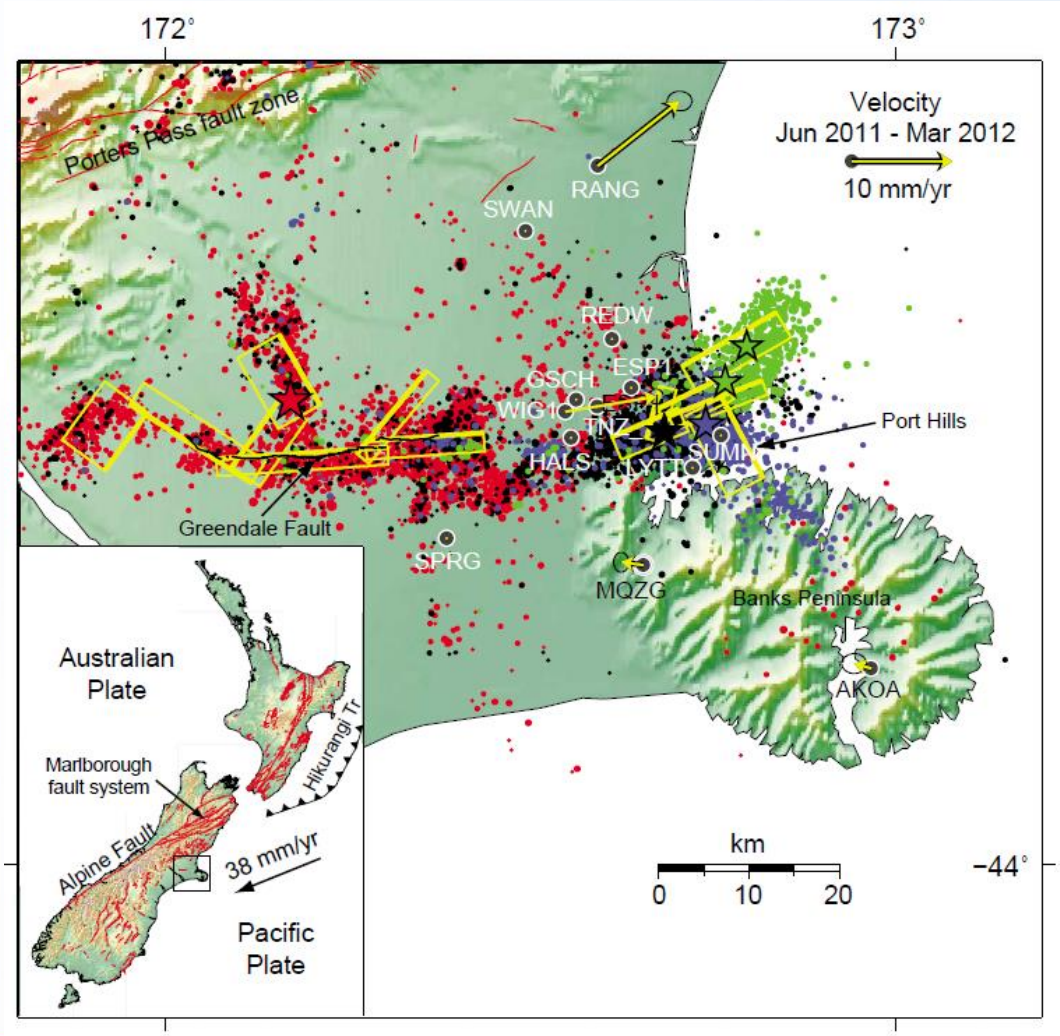


2010-11 Christchurch Earthquake Events: MQZG



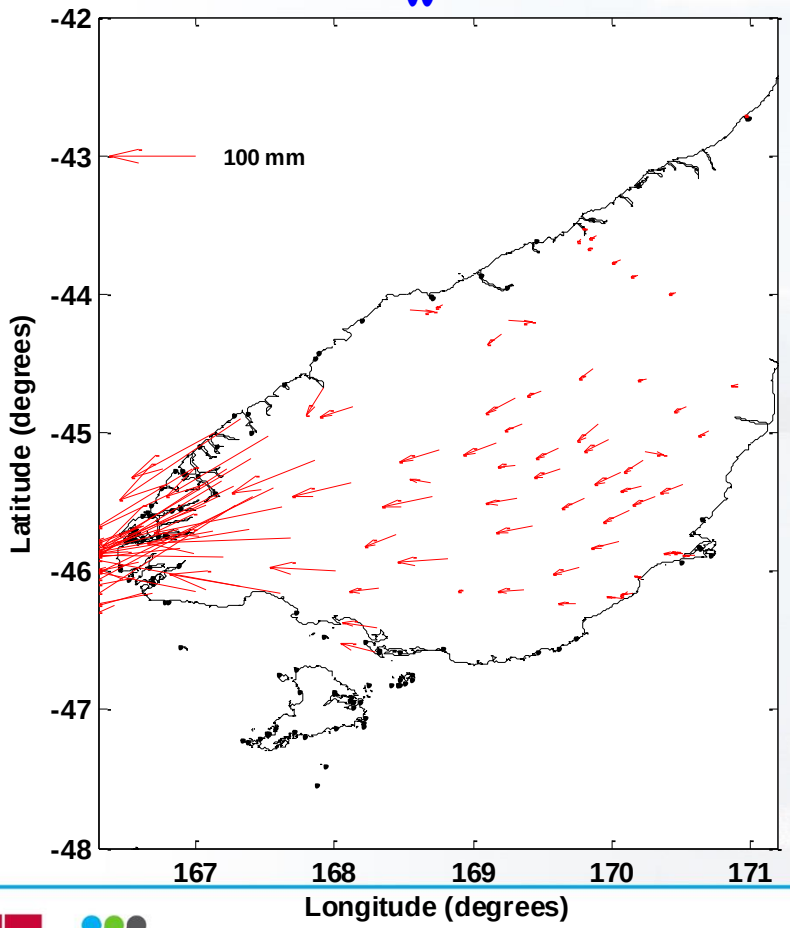


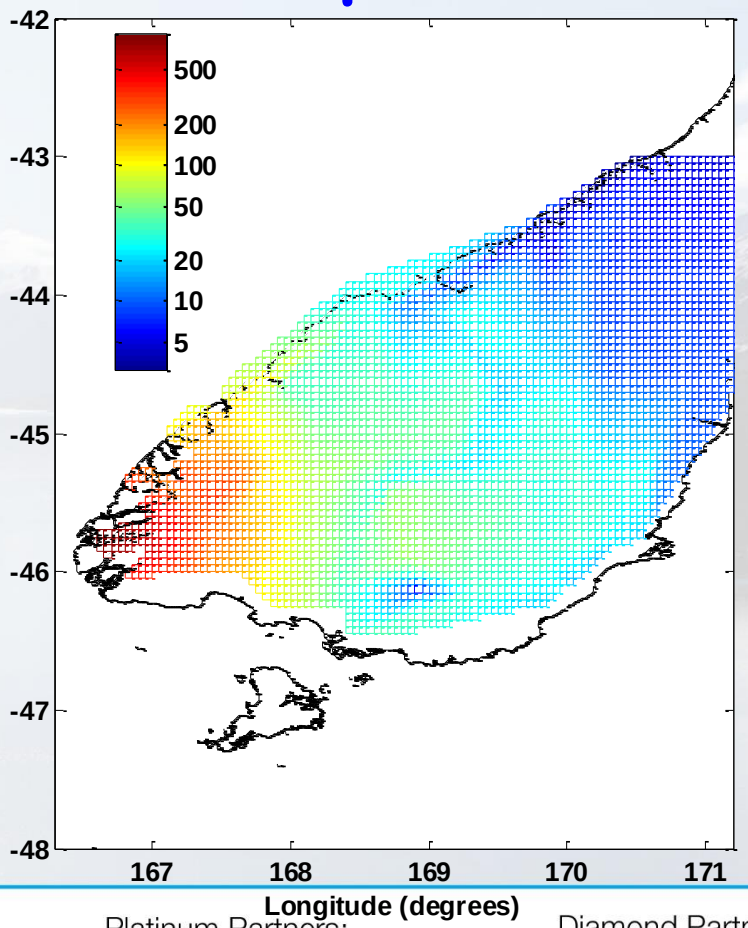
Coseismic deformation is easily modelled



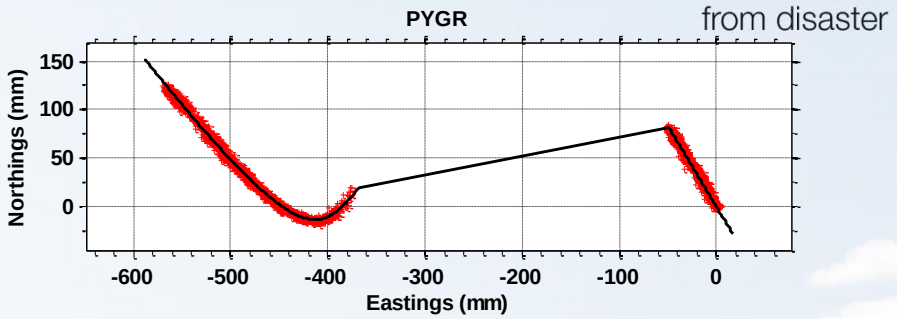
Source: GNS Science

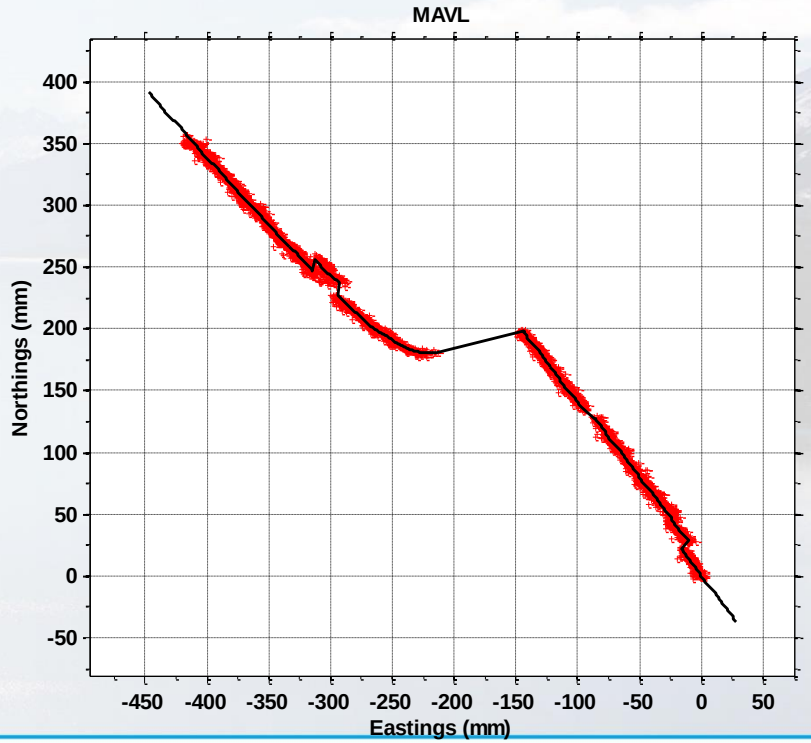
Coseismic deformation
2009 M_w 7.8 Dusky Sound earthquake





Post-seismic relaxation 2009 Dusky Sound earthquake



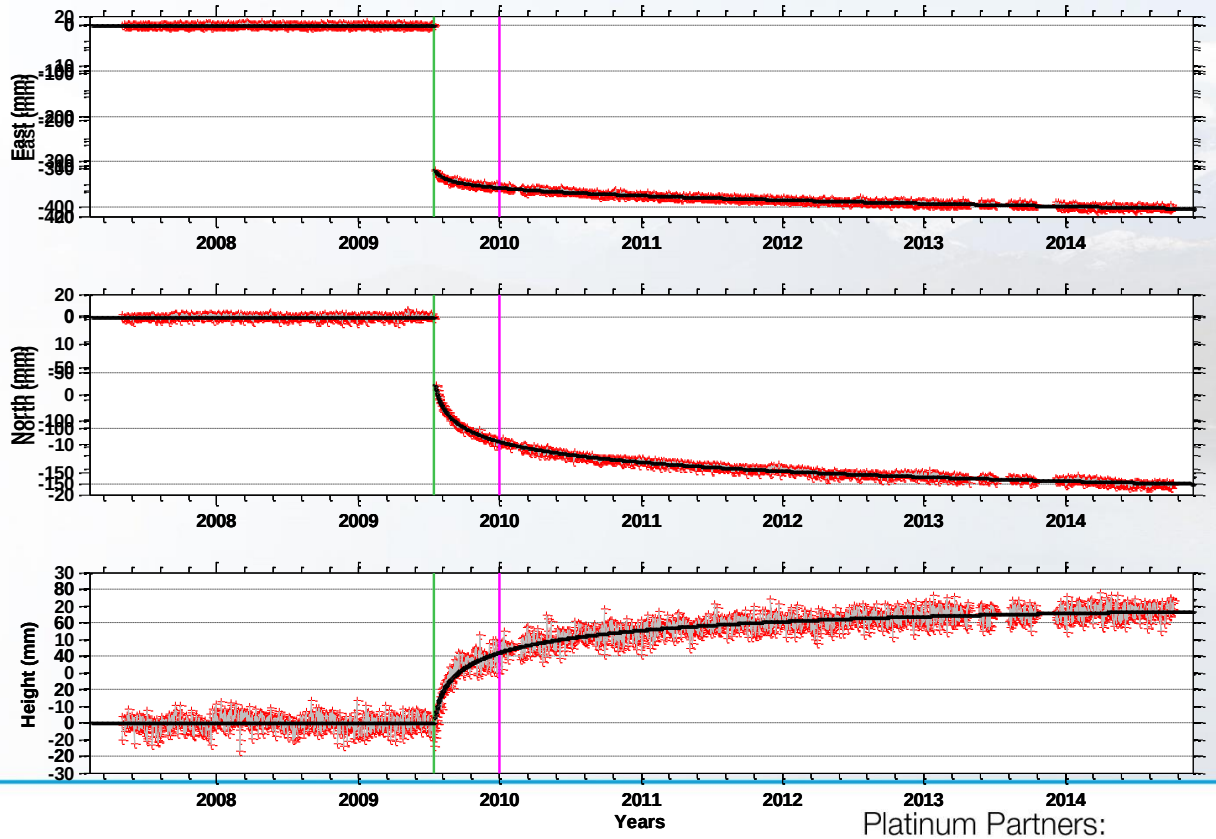


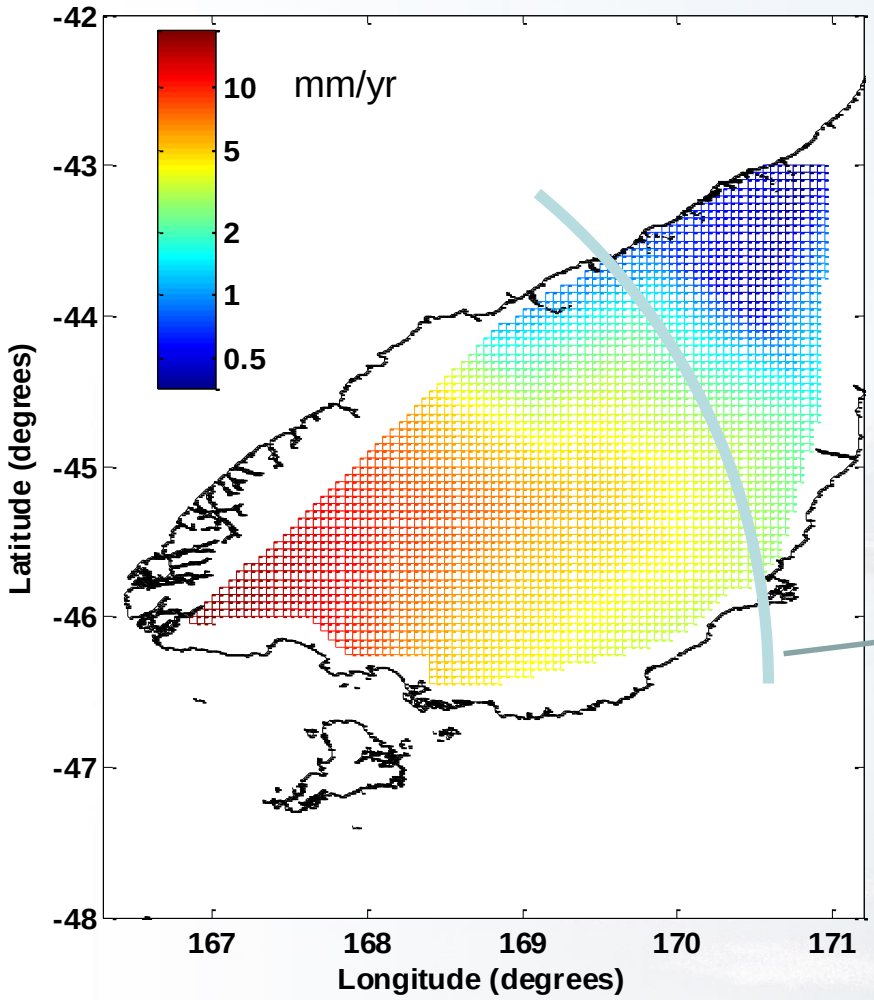
Post-seismic decay function

- logarithmic
- exponential
- power law

Post-seismic Relaxation - 2009 Dusky Sound

- Log decay function (5yrs): **E: -60** mm **N: -80** mm **H: +70** mm
- Transient velocity (5yrs): **E: -16** mm **N: -1** mm **H: 0** mm





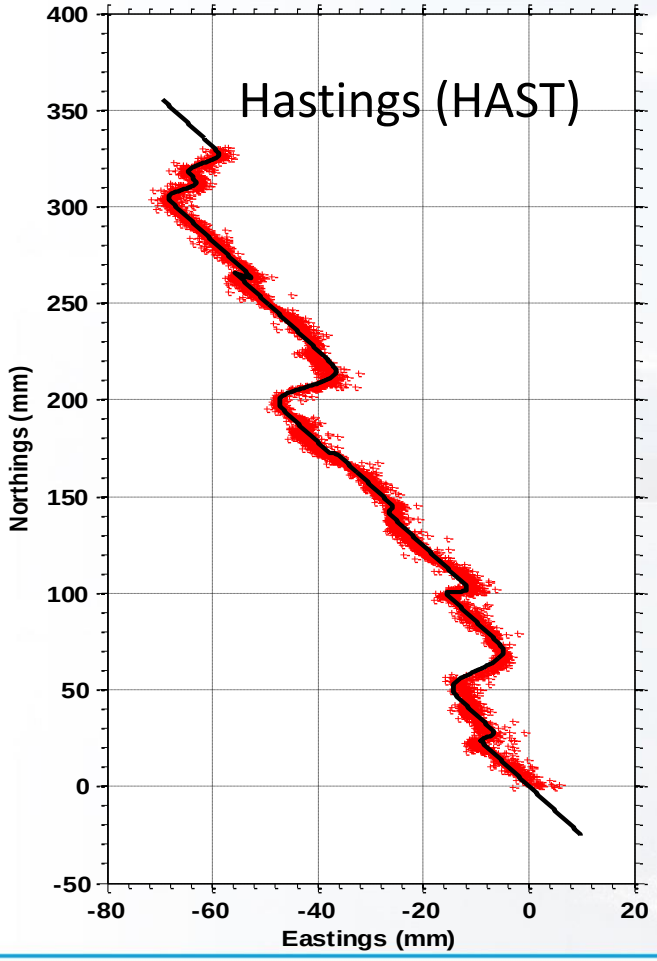
Post-seismic deformation 2009 Dusky Sound earthquake

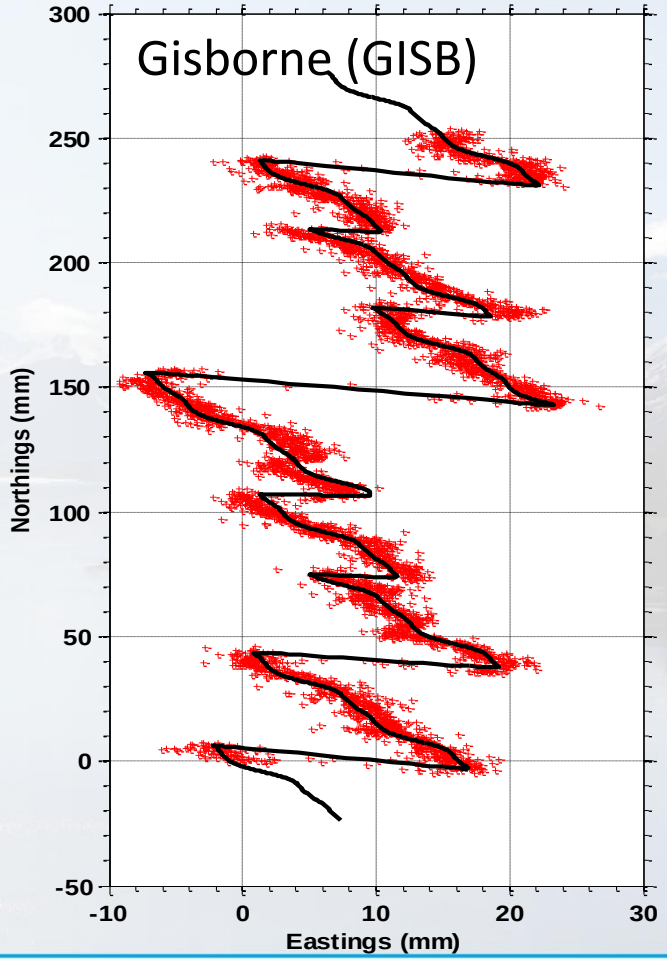
250-300 km

Post-seismic horizontal displacement after 5 years:

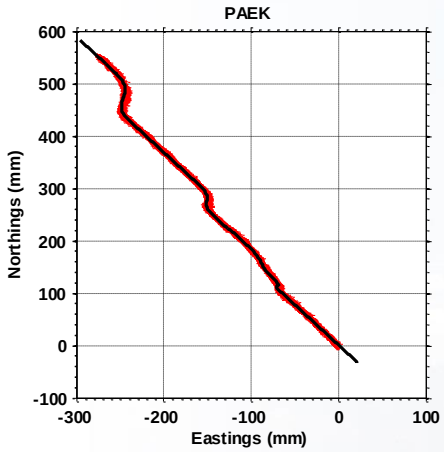
- epicentre: 100 mm
- 250-300km 20 mm

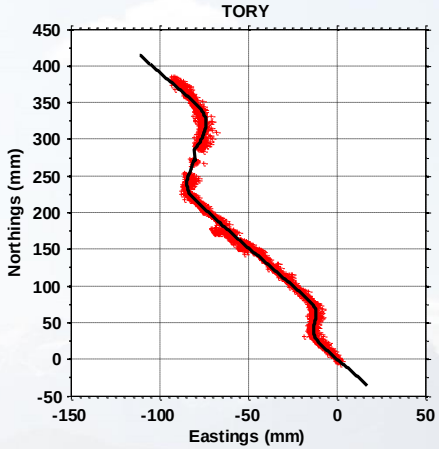
East Coast Slow Slip Events

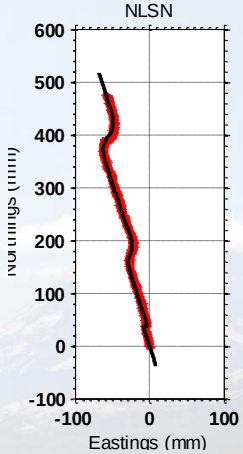


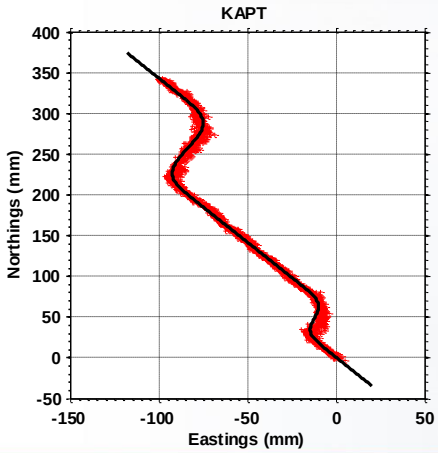


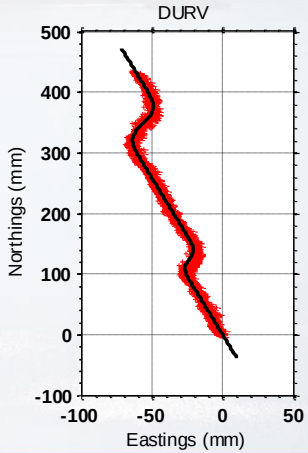
Slow Slip Events

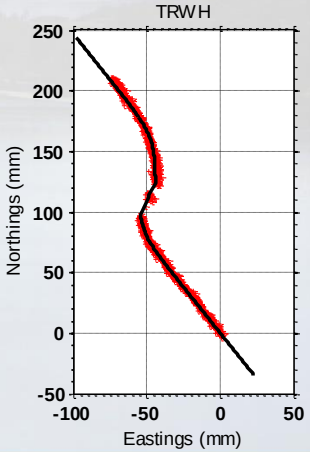




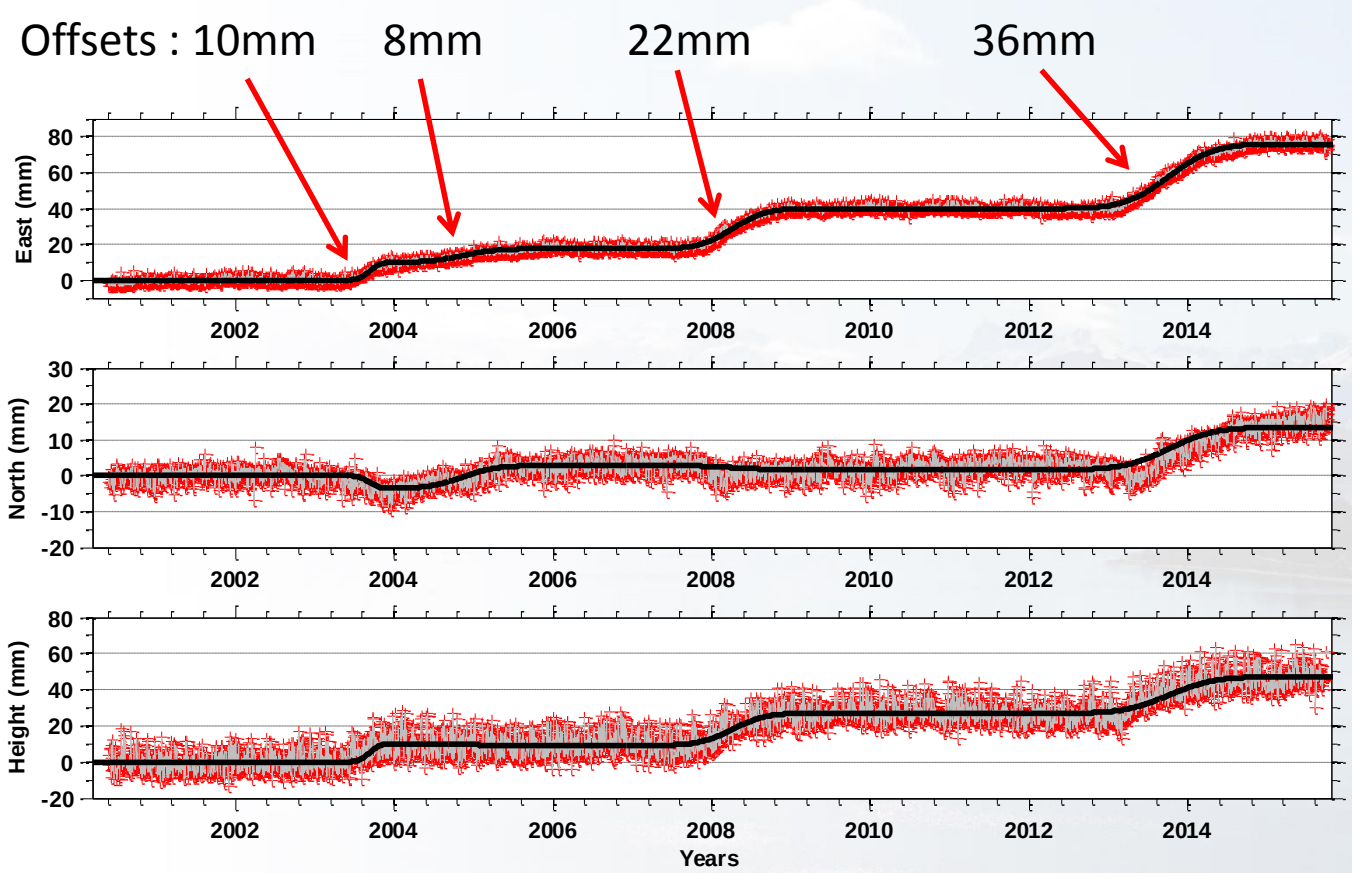


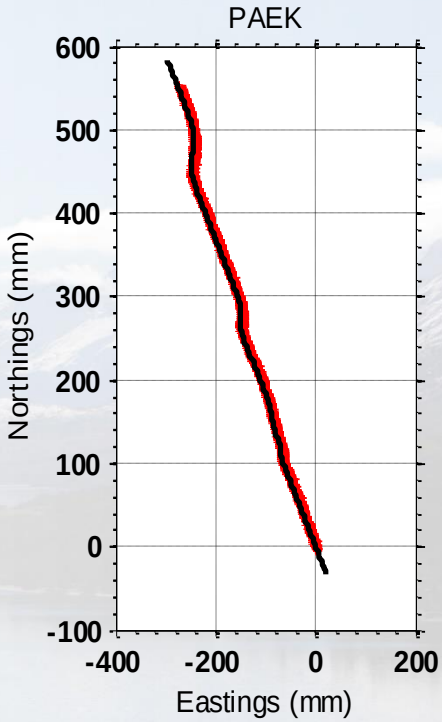






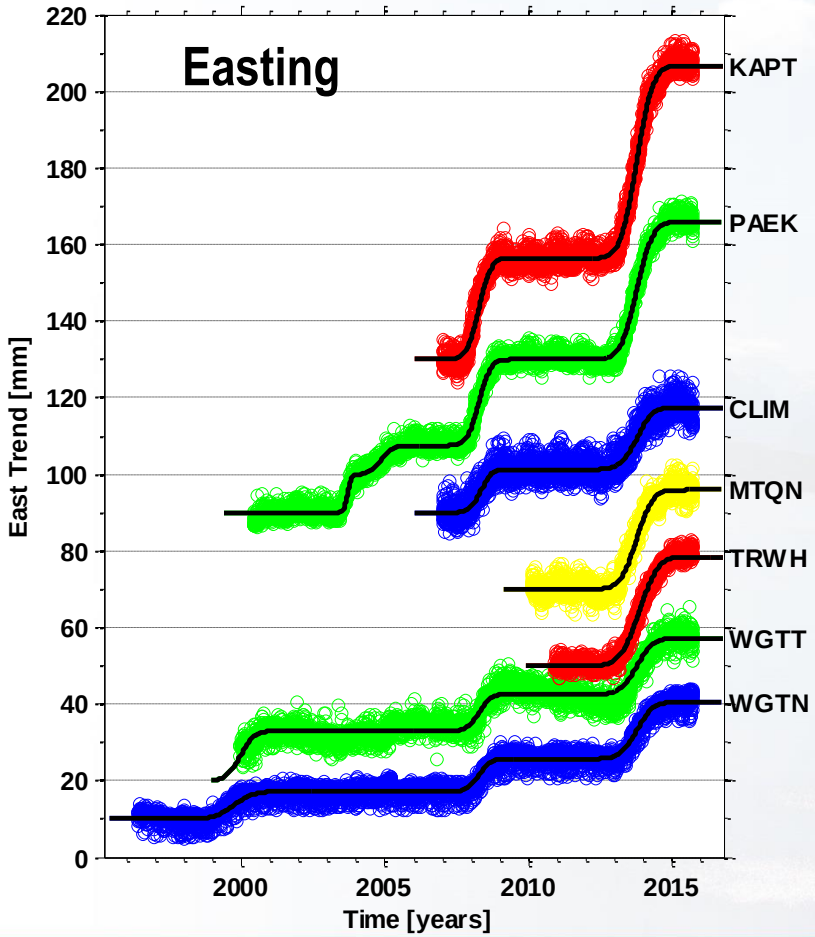
Paekakariki Hill – Slow Slip Events

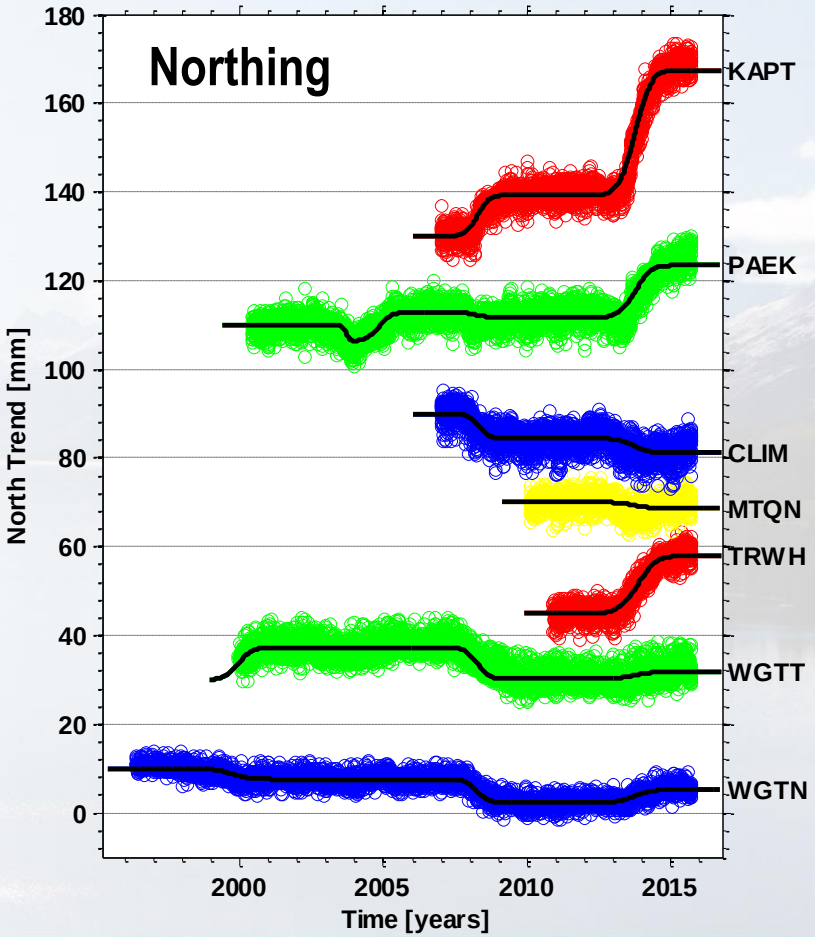




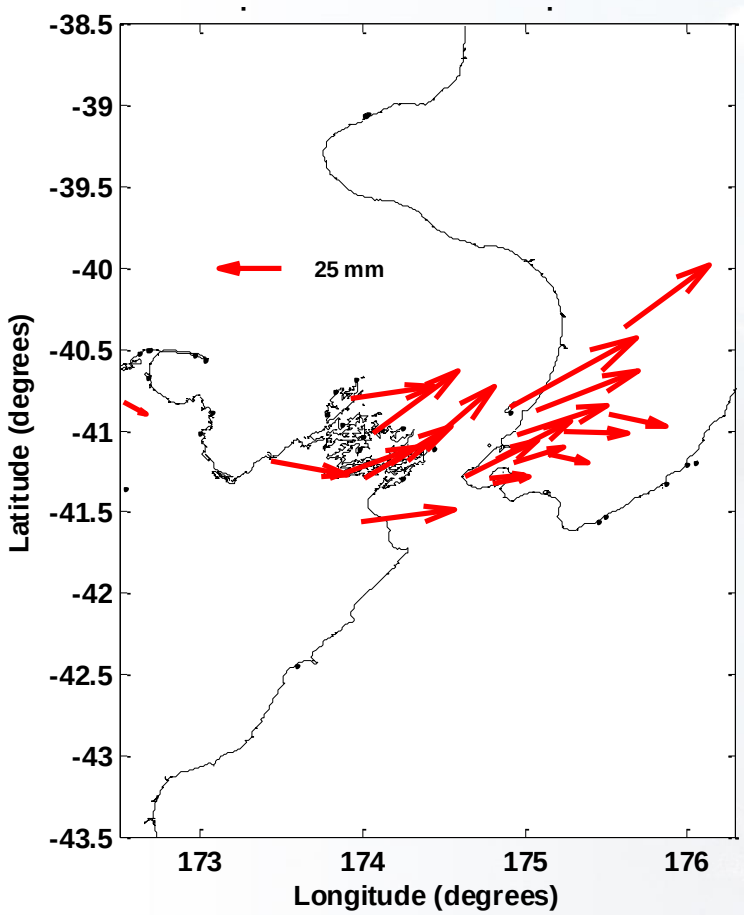
Total Offsets (over 15 years) E : +76 mm N : 13 mm H : 47 mm

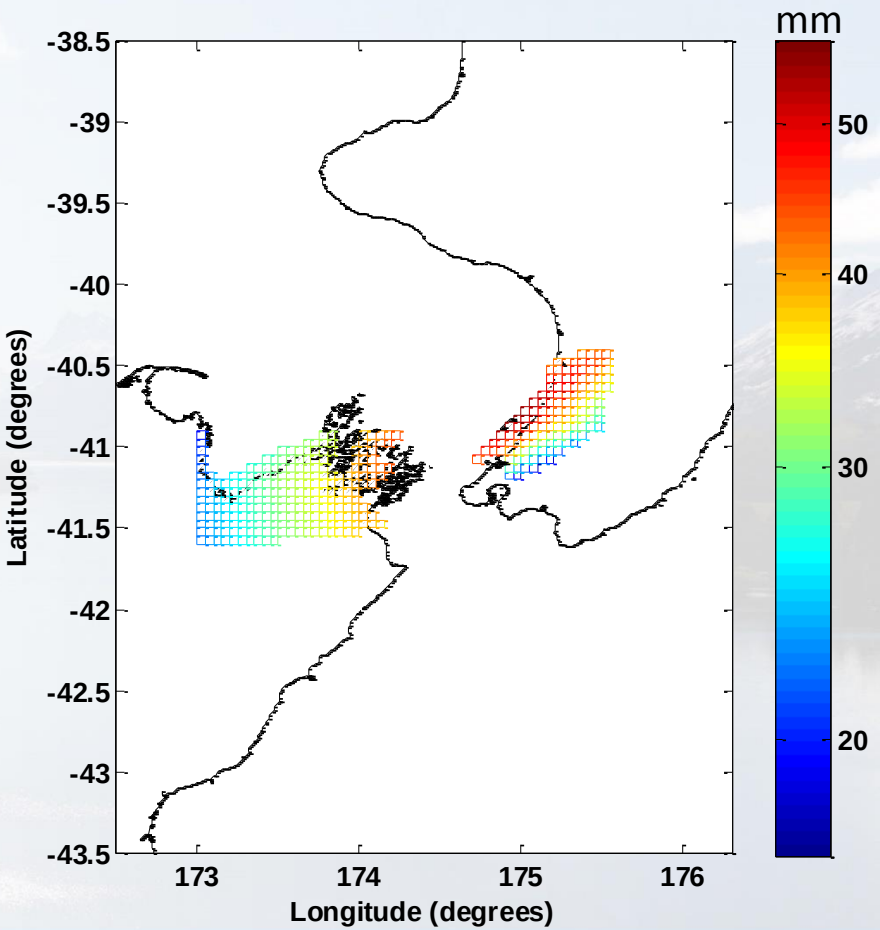
Kapiti Coast – Slow Slip Events





2013 Kapiti Coast Slow Slip Event



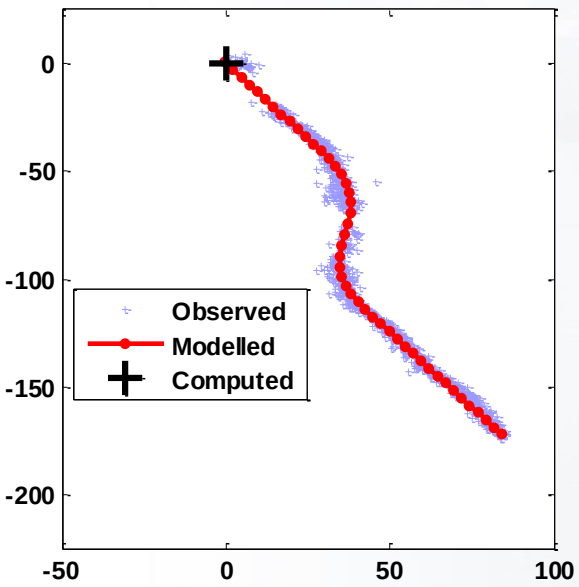


Reference Station Coordinates

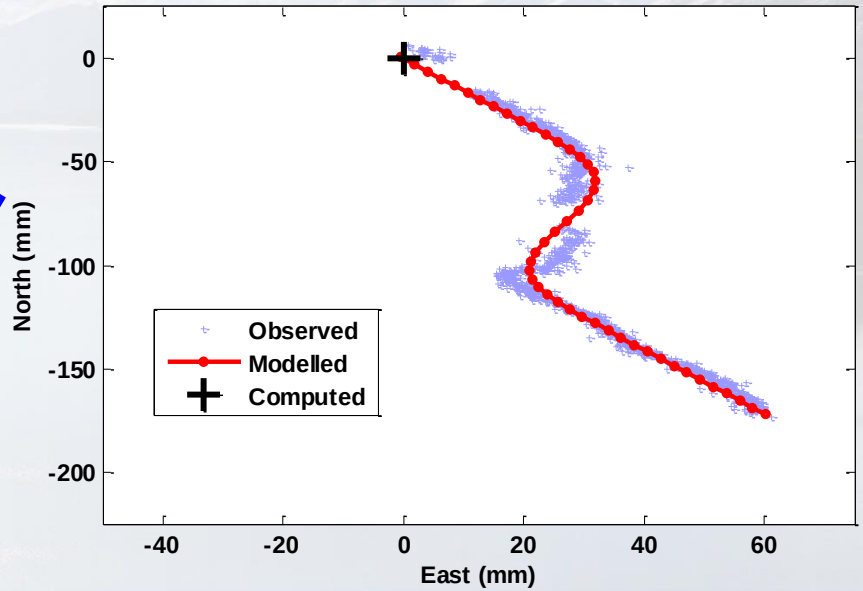
Network RTK reference stations require current epoch coordinates:

- Based on linear (uniform) velocities:
- Coordinate error up to 50 mm
- Majority of reference sites may be affected by deformation
- Non-linear trends are difficult to predict

(Data from 2011–2015)



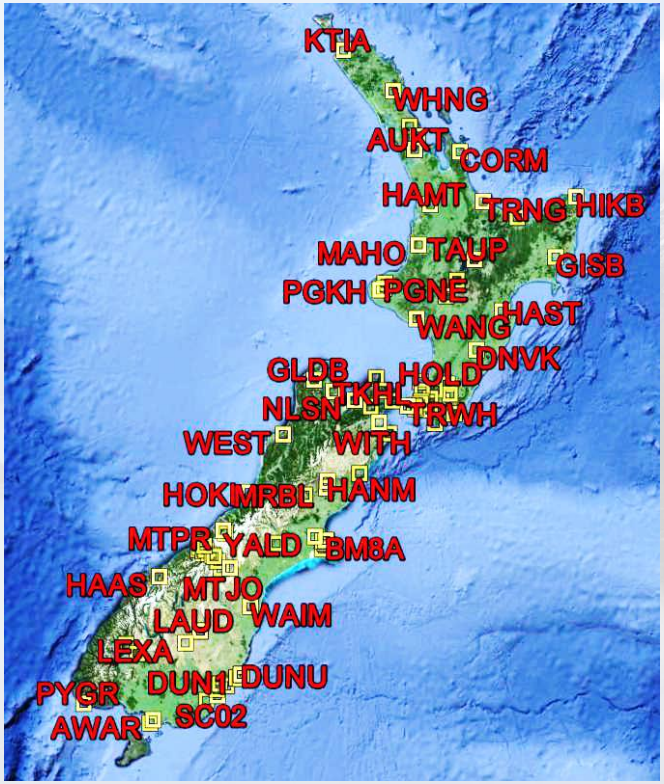
Long term linear trend



What Positioning Applications are Affected?

Long baseline applications
- Connections to PositioNZ

Current epoch coordinates applications
- i.e. ITRF2008
- PPP
- GNSS Positioning Engines
  - e.g. PositioNZ-PP, AUSPos
- Network RTK



How?
- **Reference stations:** Compute coordinates
- **User/Rover:** Transform current epoch coordinates to the user's datum
  - i.e. ITRF2008 → NZGD2000

Summary

- Active deformation in New Zealand is widespread
- Non-linear deformation can affect surveying applications
  - Especially GNSS positioning
  - Positioning over long distances

Challenges

- Monitor/Prediction of non-linear deformation
- Accurate modelling of deformation with a sparse cGNSS