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Reference Frame in Practice

Manila, Philippines 21-22 June 2013

Going Geocentric - Deformation models for Dynamic (and semi-dynamic) Datums

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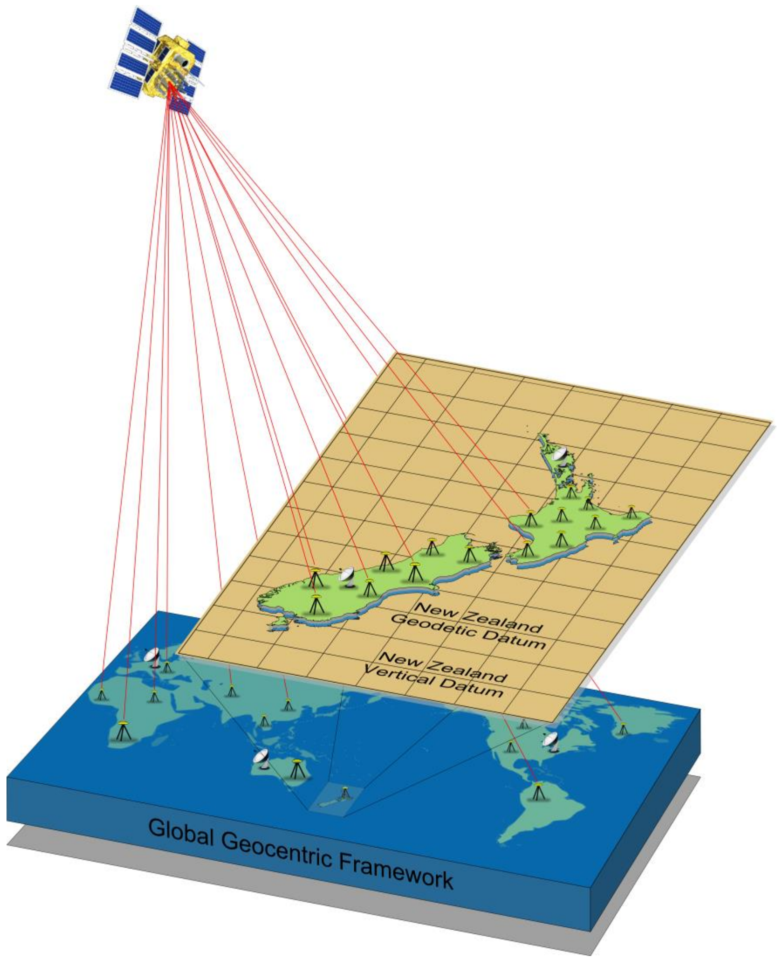
Sponsors :

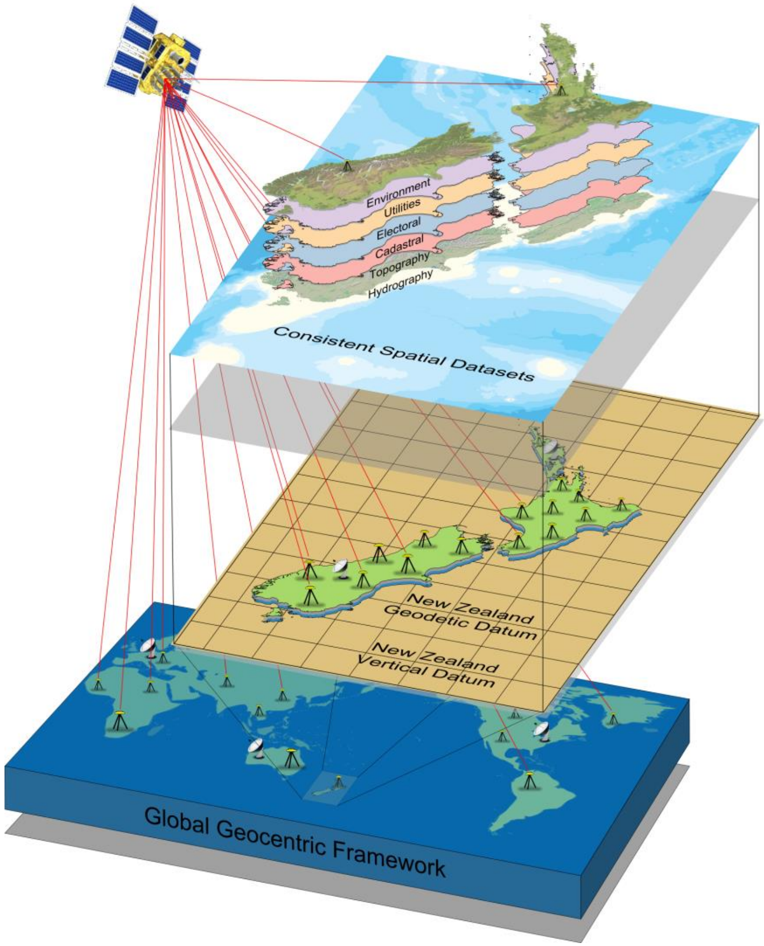
- **Introduction**
- **Concepts of 4d datums**
- **The pros and cons of static, semi-dynamic datum and dynamic datums Development of Deformation Models**
- **Incorporating the effects of events such as earthquakes into the model**
- **New Zealand Case Study (Datum Realisation and Maintenance)**
- **New Zealand Case Study (Transforming from latest ITRF to national datum)**

Introduction

Fundamental Role of Reference Frame



Fundamental Role of Reference Frame



Fundamental Role of Reference Frame

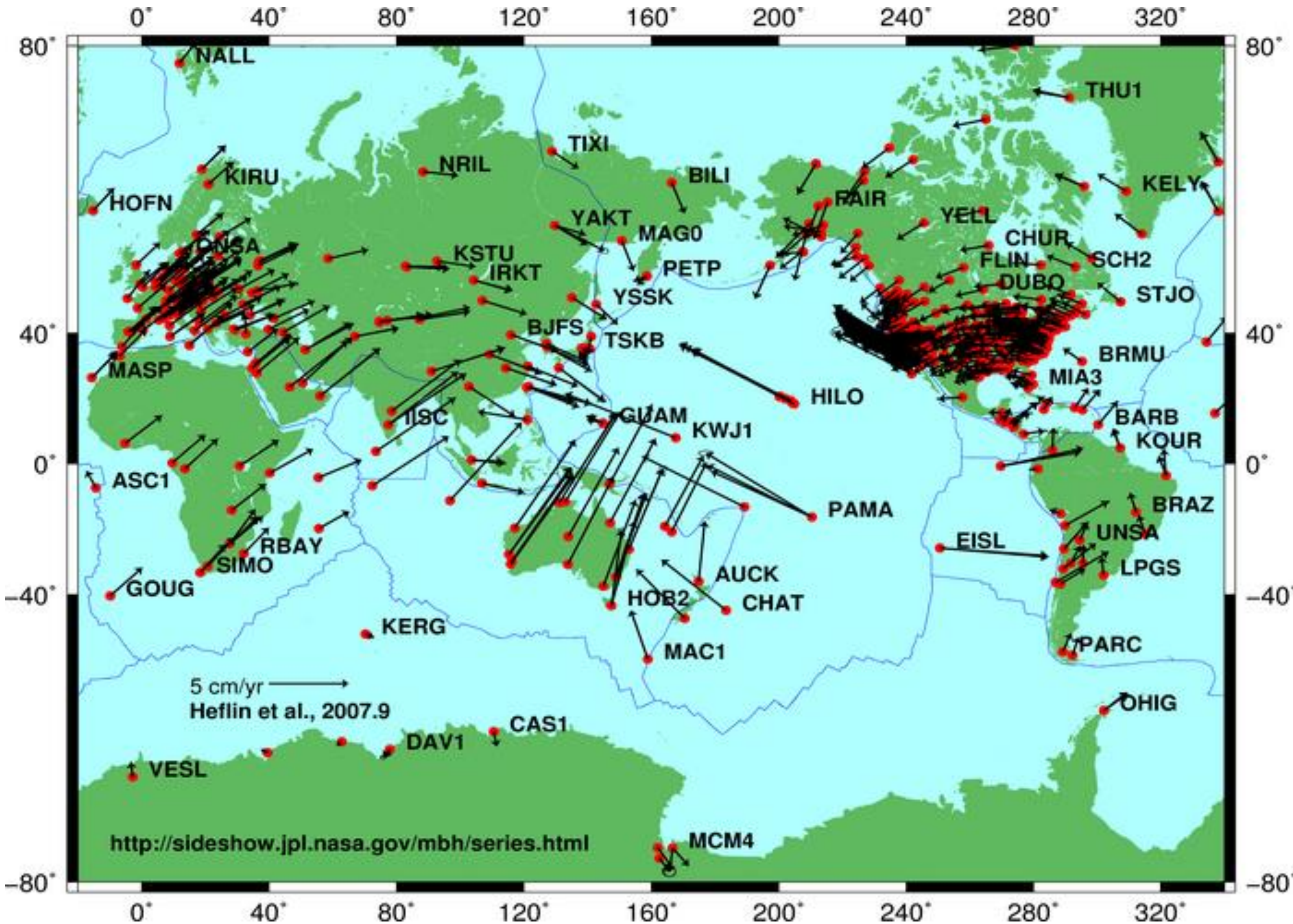
Requirements of a National Datum

- A coordinate framework that is **accurate, stable, reliable and accessible**
- Direct linkage to International Reference Frames
- **Simple** for users to connect to and use
- Physical infrastructure may include GNSS CORS and traditional geodetic survey marks
- Systems and tools to allow connection to the coordinate reference system and **transformation** of legacy data to the current reference system

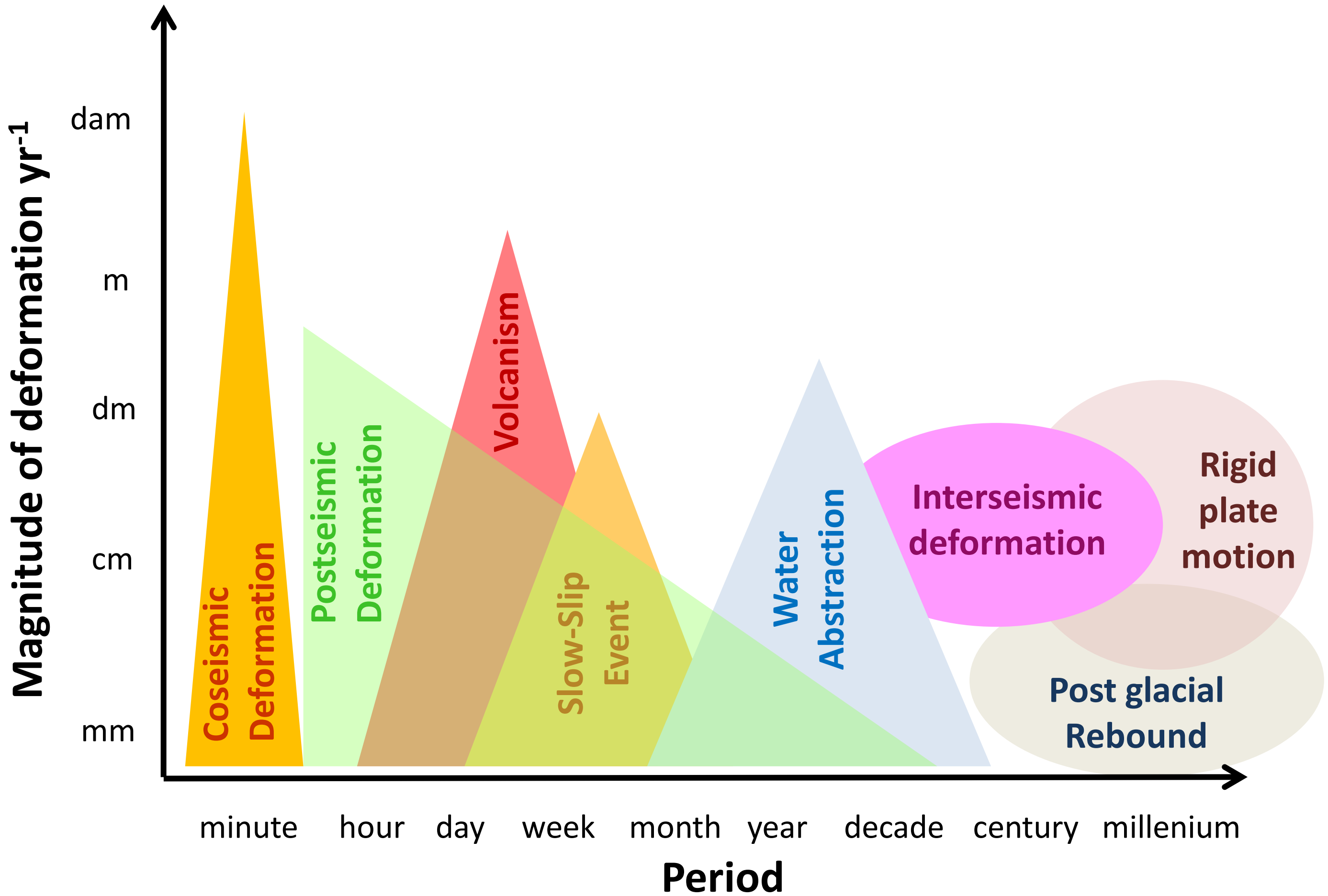
Benefits of Going Geocentric

- Compatibility with GPS/GNSS for positioning
- Compatibility with global change monitoring system
- Move towards absolute positioning – measuring position directly in terms of the centre of the Earth
- Well-understood, globally recognised transformation parameters between realisations, or at least common transformation methods
- Any future changes are likely to be small (millimetre to decimetre in absolute terms)
- Can leverage a global community of geodetic expertise

Crustal Dynamics



Temporal and spatial extent of deformation



Concepts of a 4D Datum

Datum Types

Static Datum (2D and 3D)

- Coordinates are fixed at a reference epoch
- Does not incorporate the effects of plate tectonics and deformation events
- Coordinates slowly go out of date, need to change periodically which is disruptive

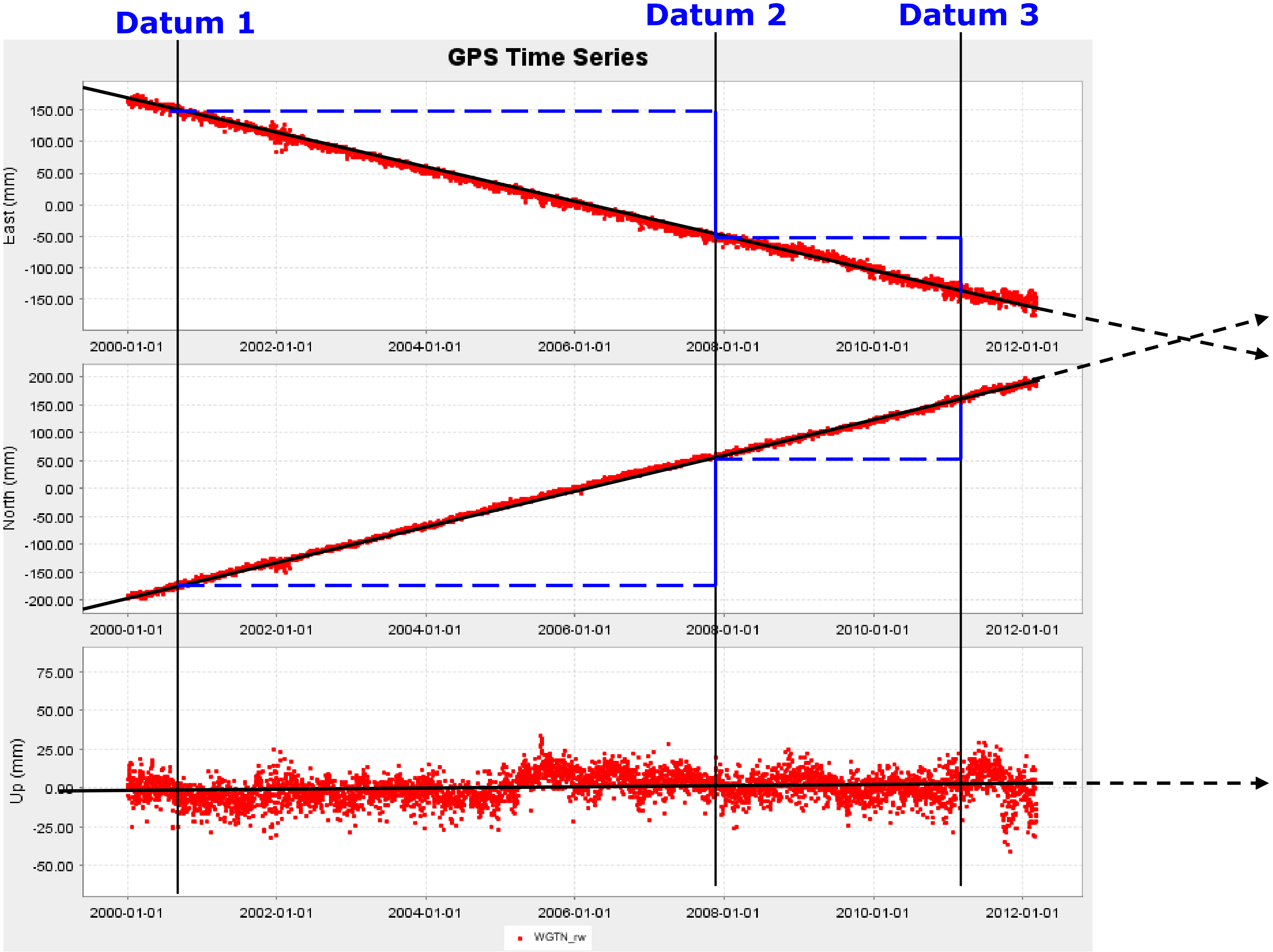
Dynamic datum (4D)

- Incorporates a deformation model to manage changes (plate tectonics and deformation events)
- Coordinates change continuously
- Can be confusing and difficult to manage

Semi - dynamic datum

- Incorporates a deformation model to manage changes (plate tectonics and deformation events)
- Coordinates fixed at a reference epoch
- Change to coordinates is minimised

Constant motion through time

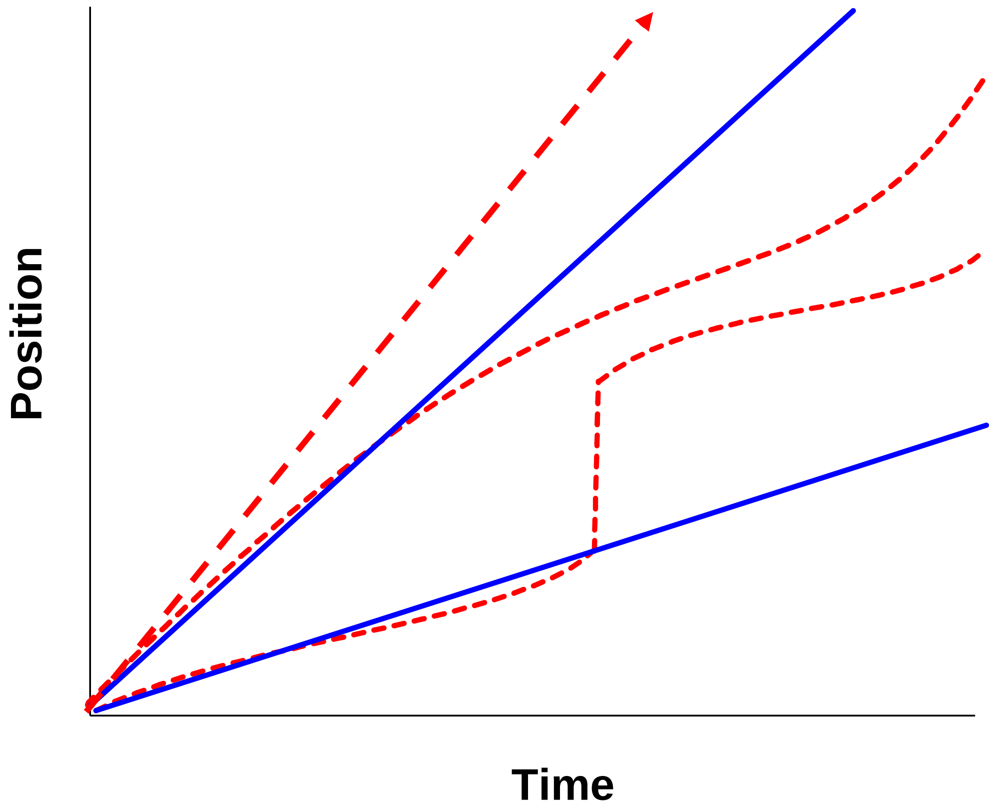


The dynamic world

The ideal world!

Need to accommodate error in model or changes in deformation

Need to accommodate local and spatially complex deformation



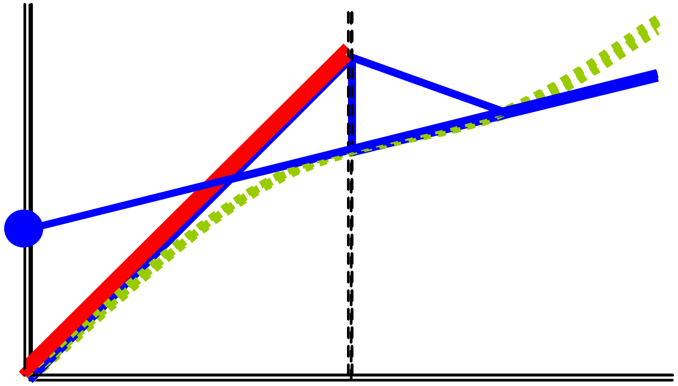
Options - Error in model or changing deformation

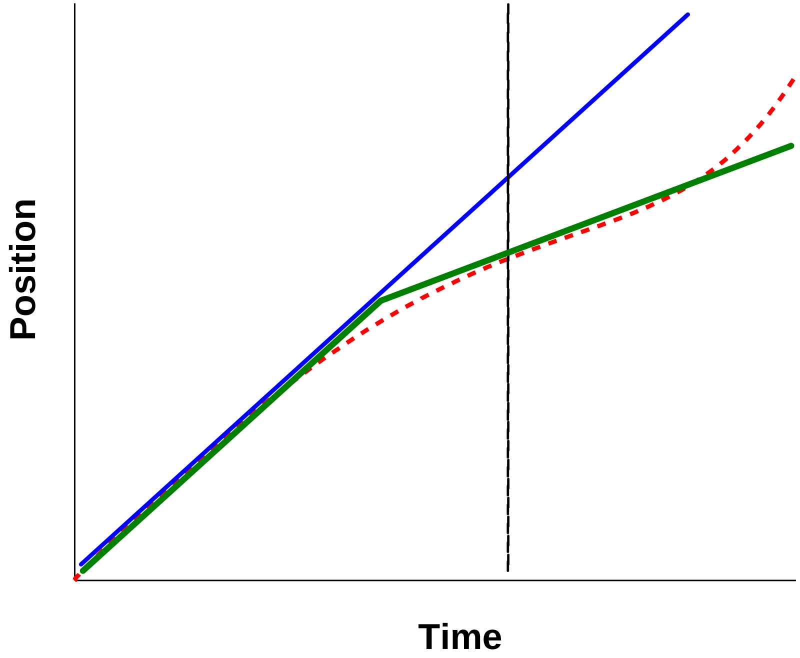
Steer to a new model

Jump to the new model

Revise the previous model

Ignore the previous model





Solution

Revise the previous model

always preserves the best estimate of past and future position and velocity

Options - Spatially complex deformation

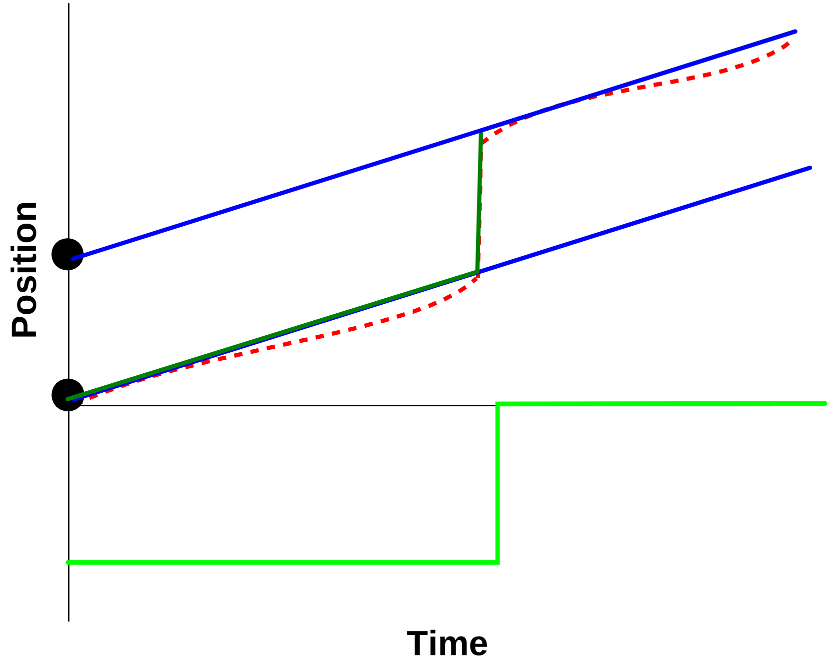
The deformation event is not incorporated into the deformation model (dot is the base epoch coordinate of the mark)

The 'patch' deformation model – in this case a discrete event

The trajectory of the mark – incorporate the national deformation model and the 'patch'

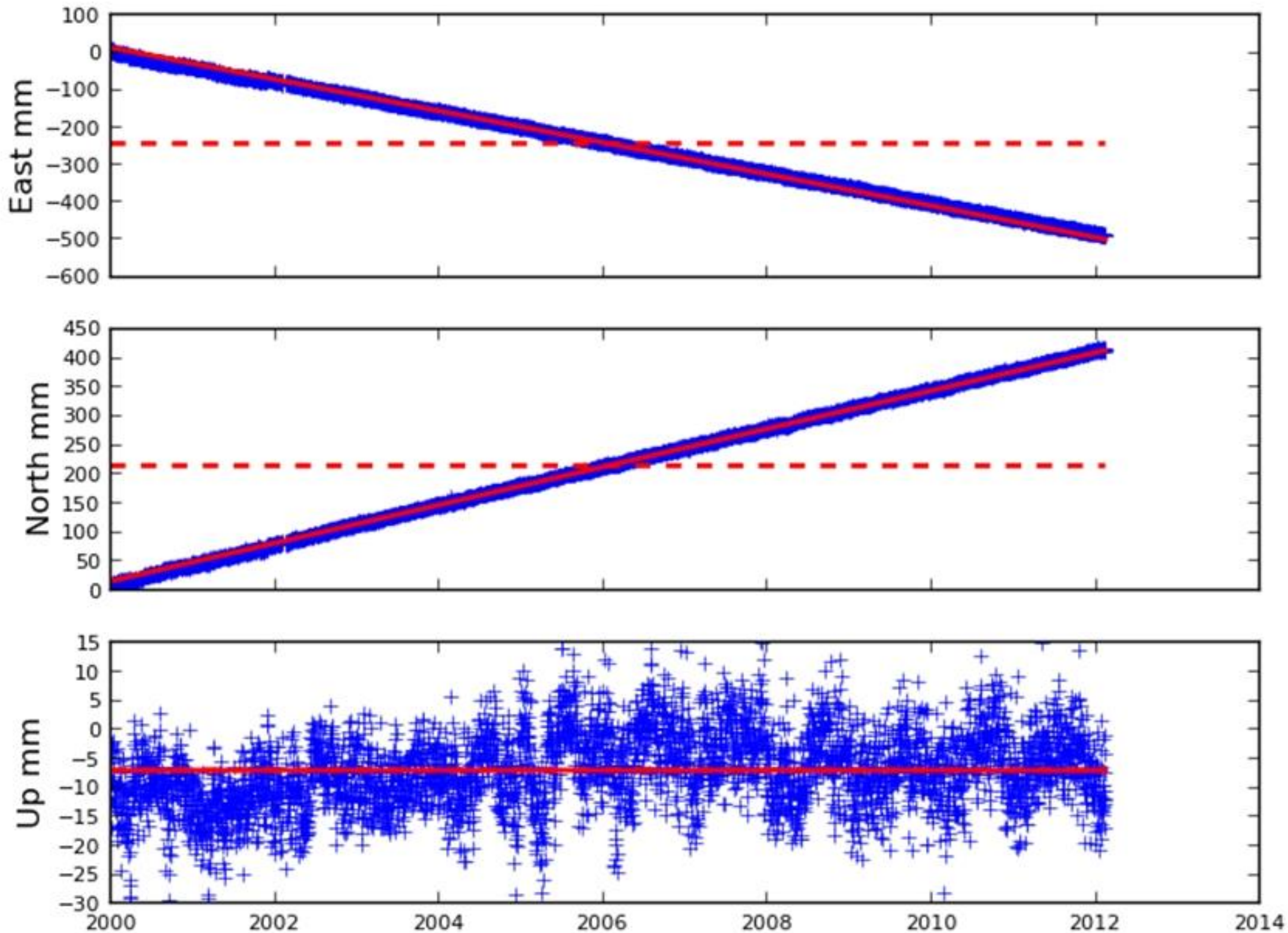
The base epoch coordinate is changed to incorporate the offset calculated from the patch

Coordinates for times after the event just use the national deformation model and coordinates before the event include the patch – "reverse patch"



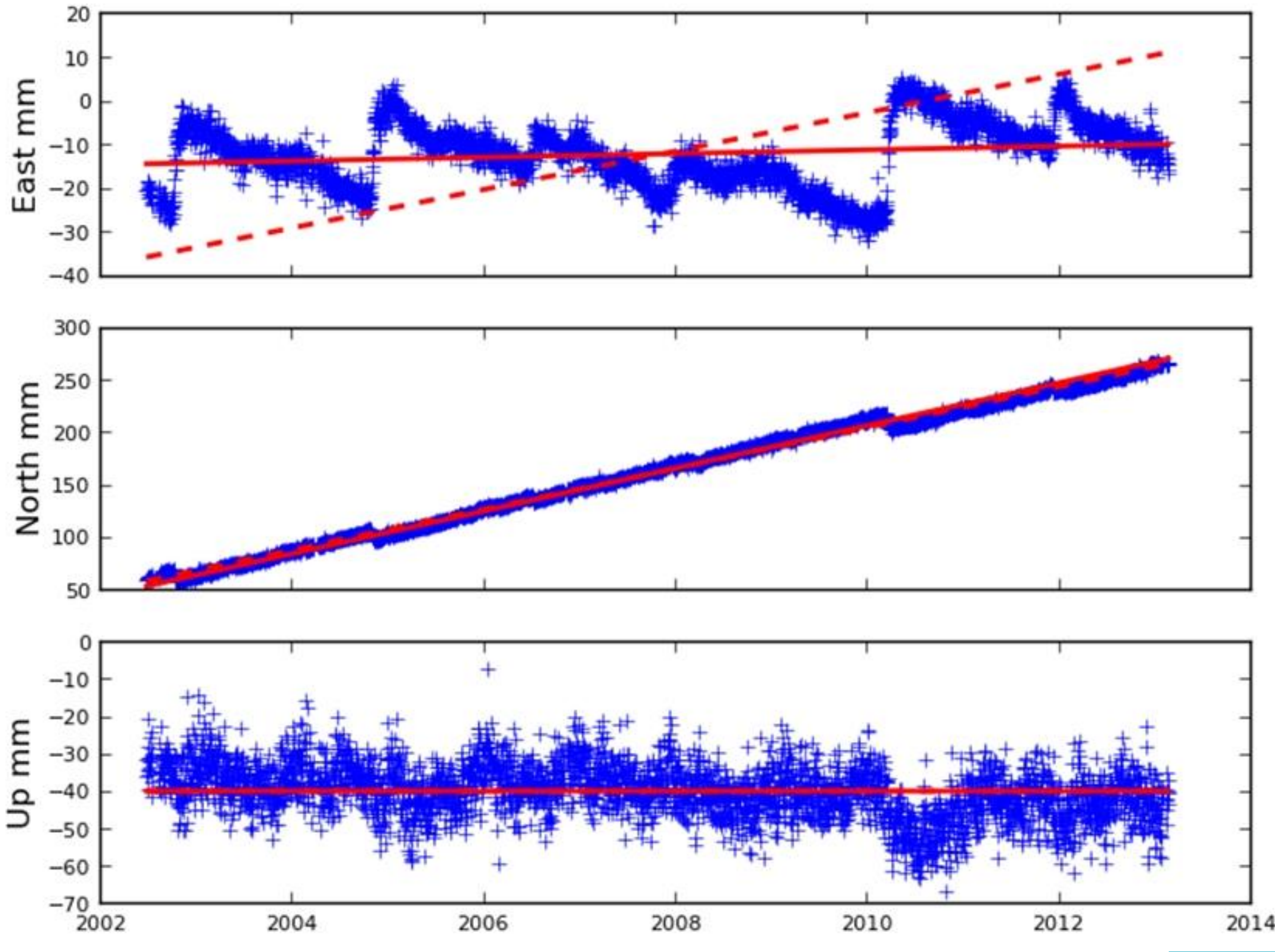
Constant motion through time

Plot of the daily IGS08 time series at CHAT. Solid red line is the predicted value from the new (2013) version of the NZGD2000 deformation model. Dashed red line is the predicted value from the original deformation model. Note that time series are not corrected for non-tectonic effects such as antenna changes.



Episodic events

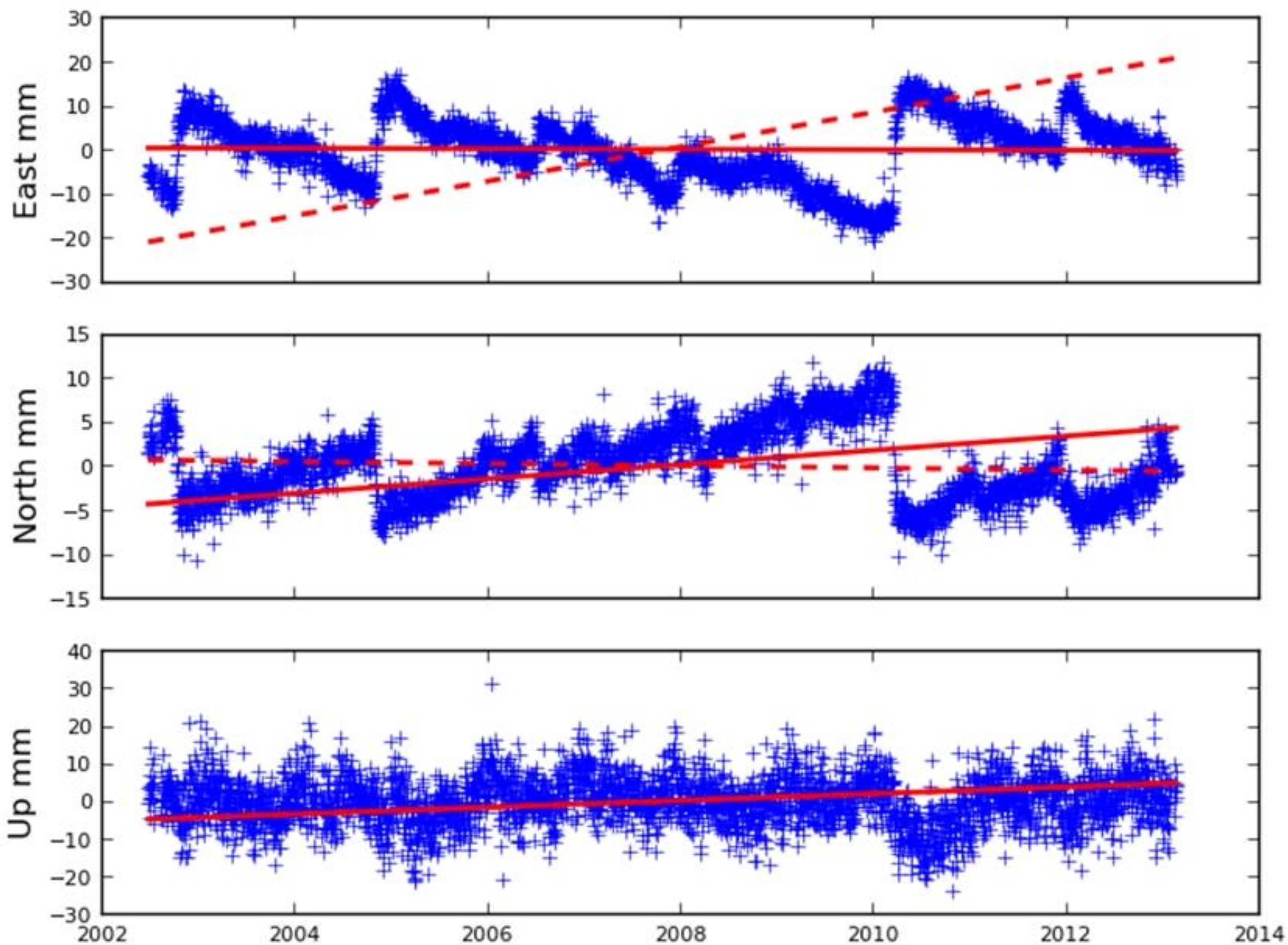
Plot of the daily IGS08 time series at GISB. Solid red line is the predicted value from the new (2013) version of the NZGD2000 deformation model. Dashed red line is the predicted value from the original deformation model. Note that time series are not corrected for non-tectonic effects such as antenna changes.



Episodic events - Detrended

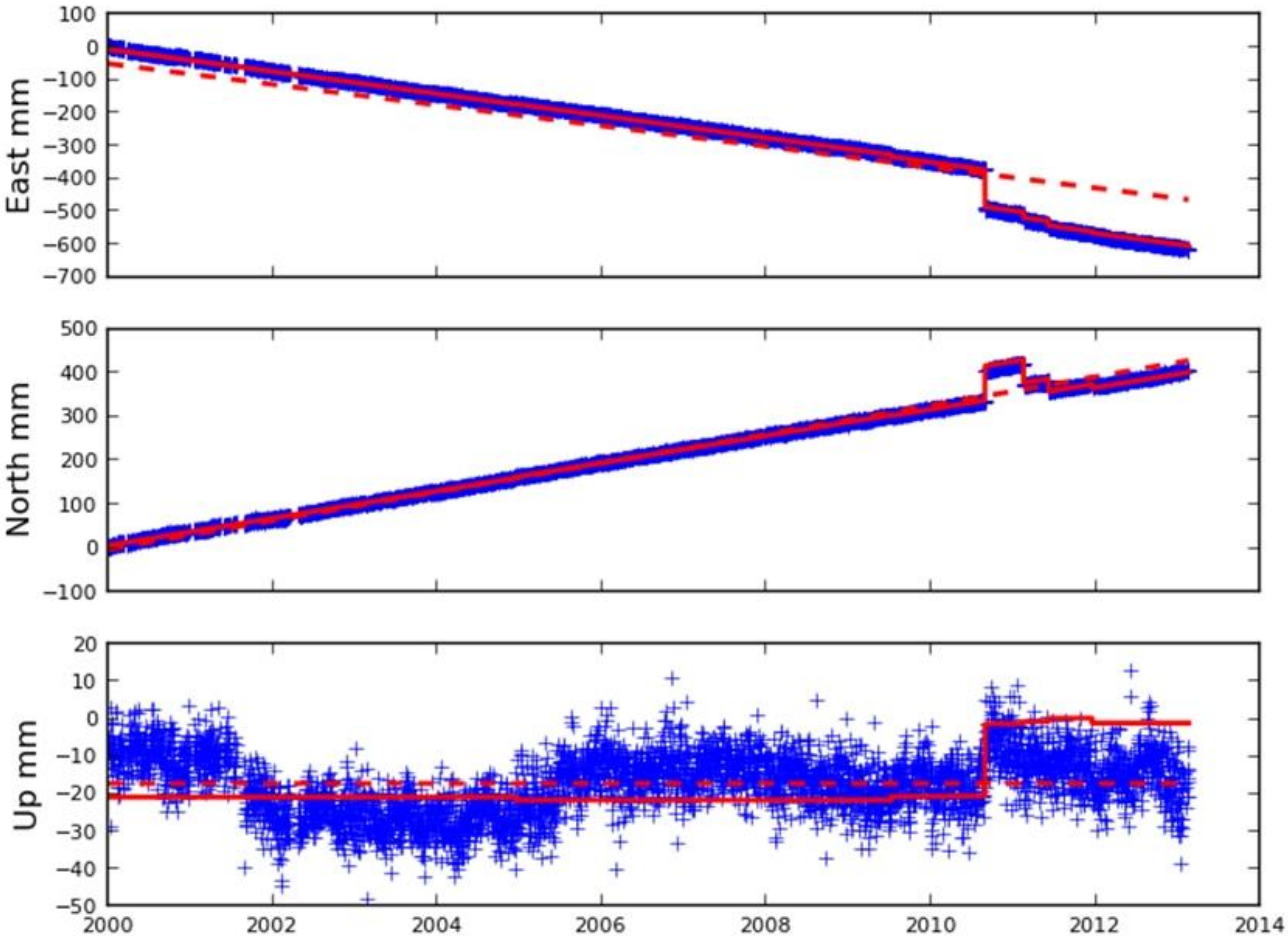
Plot of the daily IGS08 time series at GISB. Solid red line is the predicted value from the new (2013) version of the NZGD2000 deformation model. Dashed red line is the predicted value from the original deformation model. Note that time series are not corrected for non-tectonic effects such as antenna changes.

The trend has been removed from the observed and calculated values based on a fit through the observed values.



Multiple events

Plot of the daily IGS08 time series at MQZG. Solid red line is the predicted value from the new (2013) version of the NZGD2000 deformation model. Dashed red line is the predicted value from the original deformation model. Note that time series are not corrected for non-tectonic effects such as antenna changes.



Modelling the deformation

Options – regional deformation

– Simple rectangular grid (simplest method)

– Complex grid (eg curvilinear grid)

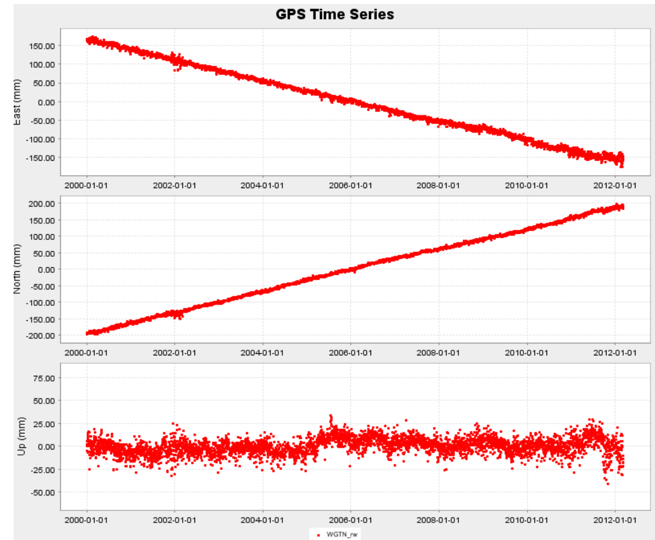
Options – complex deformation

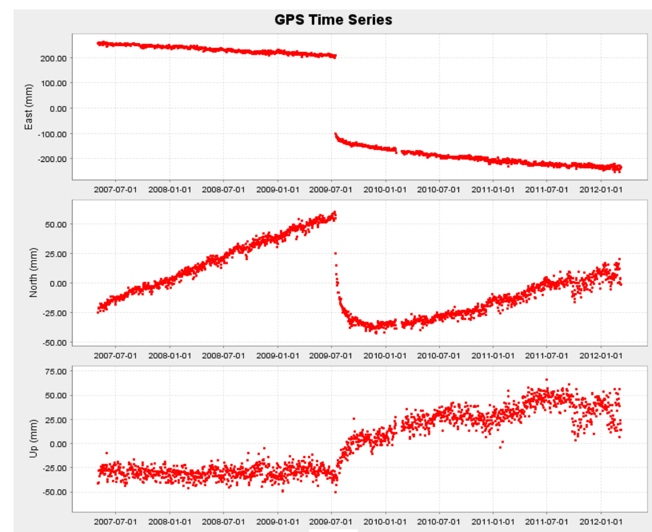
– Densify the national deformation model (model becomes very complex)

– need a detailed triangulated grid – becomes complex

– define a local ‘patch’ for the model (covers the area of the event with zero deformation at the boundaries)

– change coordinates





The pros and cons of static, semi-dynamic and dynamic datums

Datum types

Static Datum

- Coordinates are fixed at a reference epoch
- Does not incorporate the effects of plate tectonics and deformation events
- Coordinates slowly go out of date, need to change periodically which is disruptive

Dynamic datum

- Incorporates a deformation model to manage changes (plate tectonics and deformation events)
- Coordinates change continuously
- Can be confusing and difficult to manage

Semi - dynamic datum (NZGD2000)

- Incorporates a deformation model to manage changes (plate tectonics and deformation events)
- Coordinates fixed at a reference epoch
- Change to coordinates is minimised

Advantages of a Dynamic or Semi-dynamic Datum

Maintains alignment with underlying global reference frames - ITRF

Lengthen the life of the datum

New observations can be integrated with old observations

Spatial accuracy of the geodetic network/datum is maintained or increased

Enables non-expert users to be isolated from the complexities of the dynamics (semi-dynamic datum only)

For practical purposes appears as a static datum (semi dynamic datum only)

Disadvantages of a Dynamic or Semi-dynamic Datum

Limited by the accuracy of the deformation model

Model can become complex over time to incorporate the effects of deformation events (e.g. earthquakes)

Coordinates need to be time tagged – cause confusion (dynamic datum only)

Most users do not know how to use a deformation model which is required to work with a dynamic datum

If using real time systems (CORS networks) need to use the deformation model to manage real time coordinates (semi-dynamic datums only)

Issues to consider

Accommodate vertical deformation

– vertical deformation trends may be obscured by much larger localised episodic or cyclic events

– triangulated or other irregular grid probably required

Latency

– may be considerable time between a deformation event and the 'patch' being implemented

– for discrete events deformation may continue for some time requiring different versions of the patch

Extension Offshore

– how do you model deformation offshore?

– offshore may need to incorporate global model – express velocities as global rotations

Changing Reference Epoch

– may ultimately need to change the reference epoch once coordinates become inconveniently different from true current positions (semi-dynamic datum only)

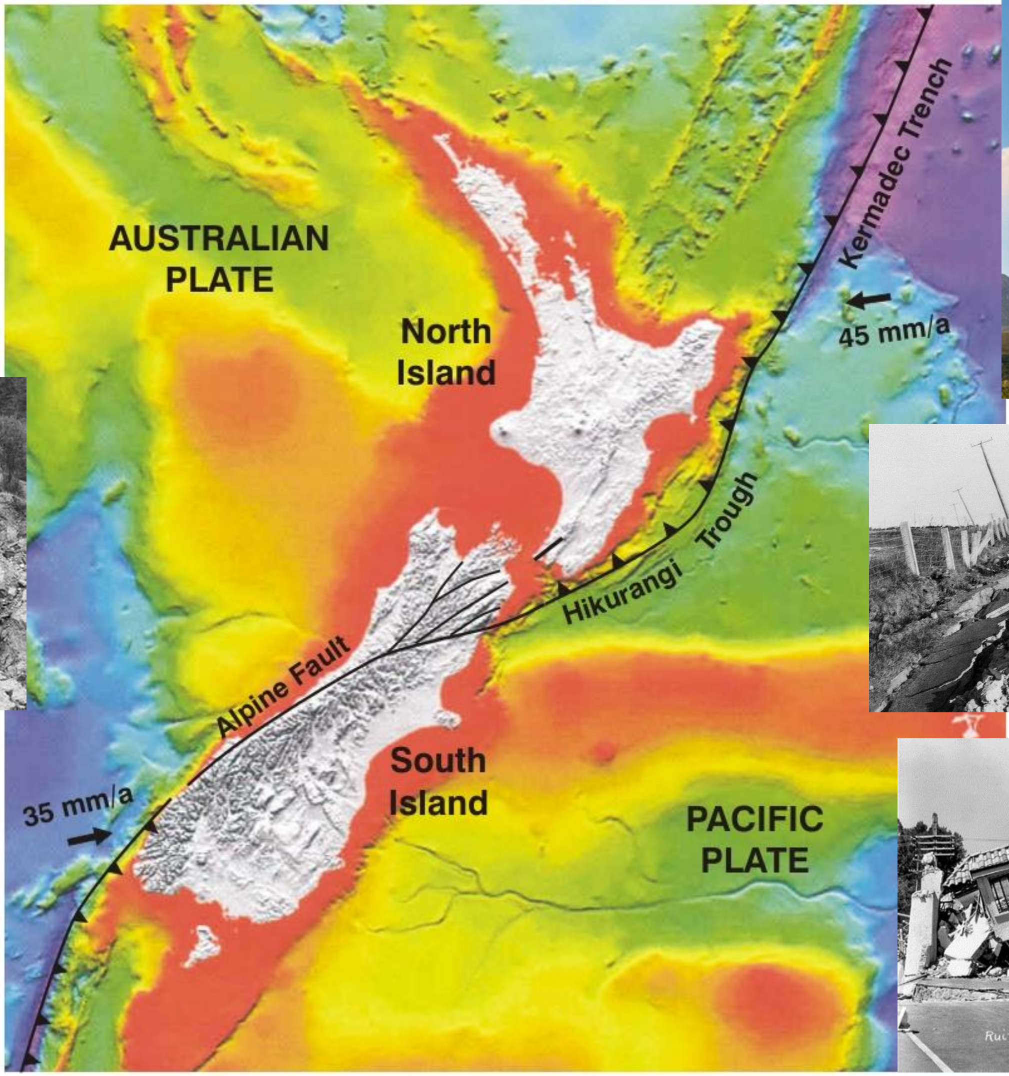
Joining adjacent jurisdictions/datums

New Zealand Case Study

UNSW
THE UNIVERSITY OF NEW SOUTH WALES
SYDNEY · CANBERRA · AUSTRALIA

We don’t live on a stable planet

Land Information New Zealand
Toitū te whenua



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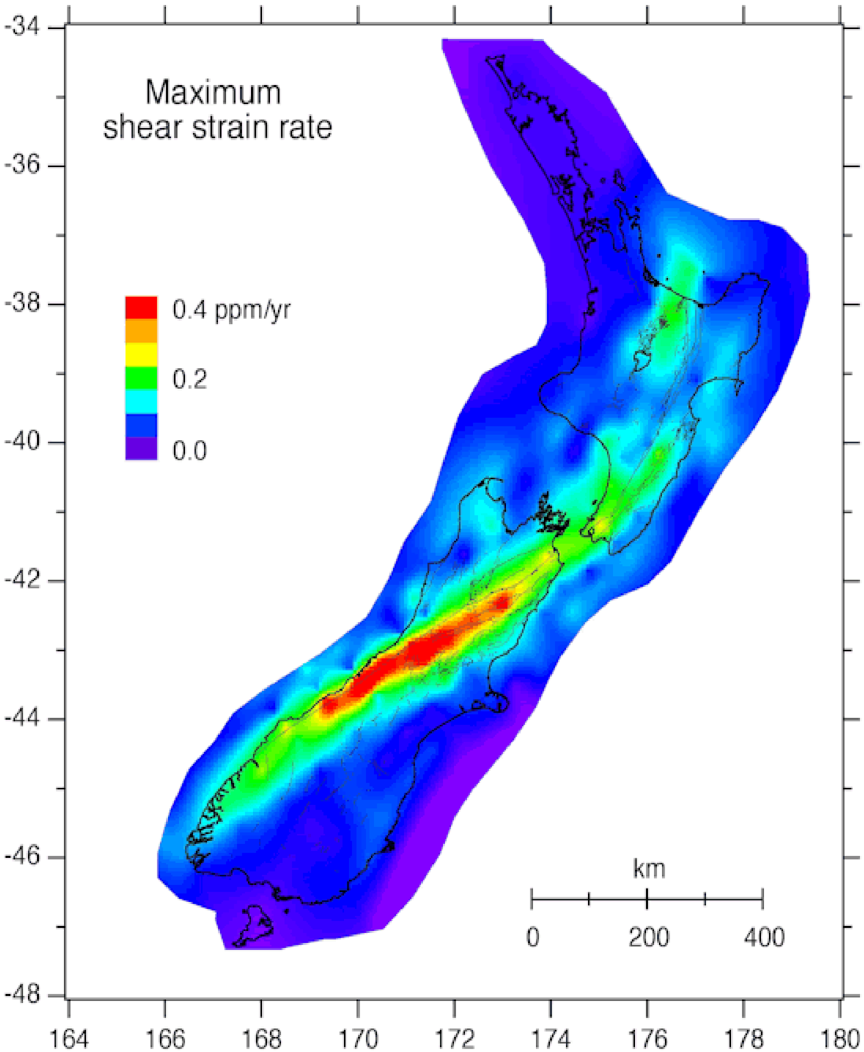
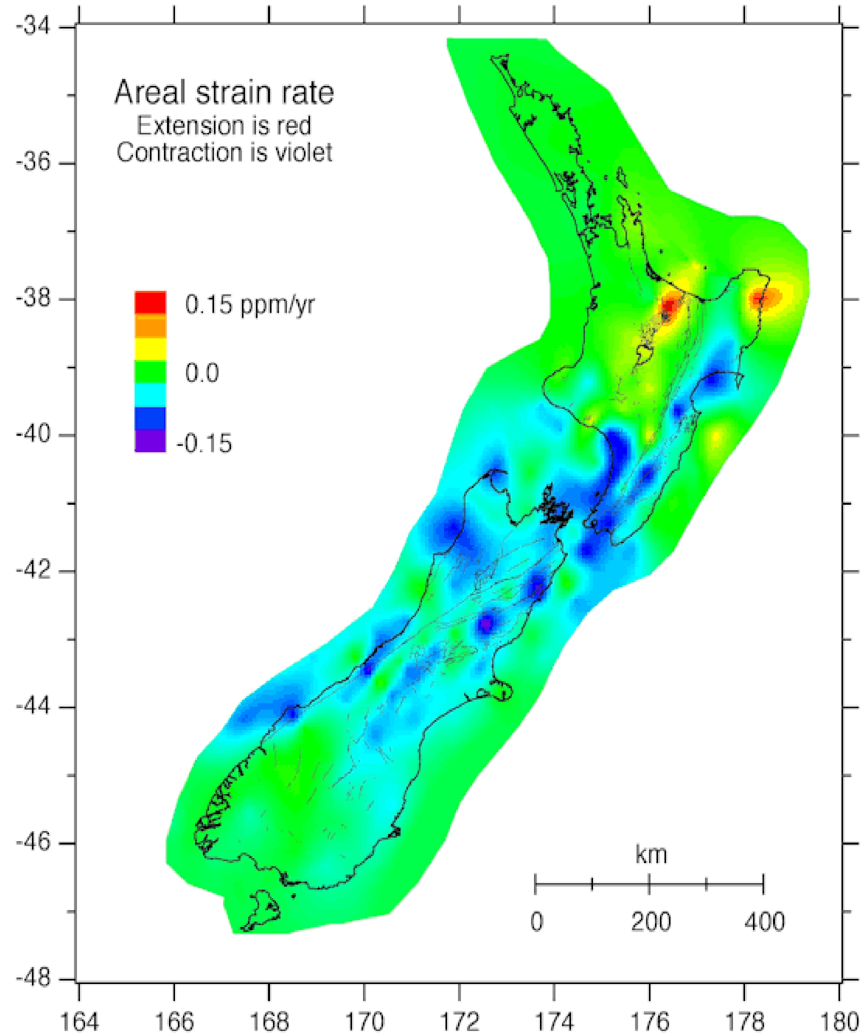
Measuring deformation - strain

Land Information New Zealand Toitū te whenua





Limitations with NZGD49

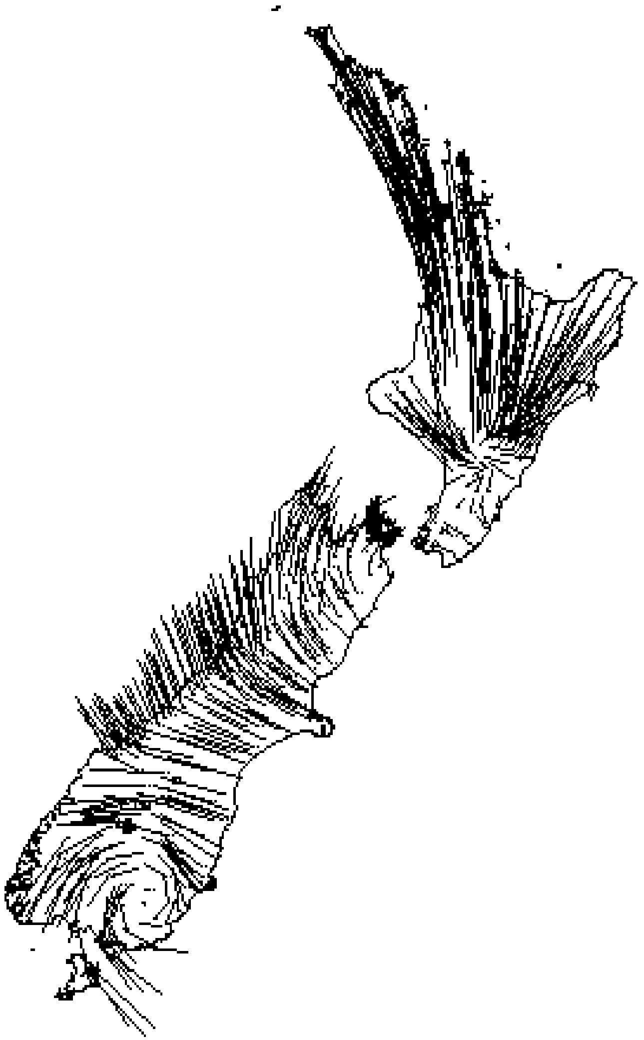
Regional distortions up to 5m present

Built up in a piecemeal fashion

Incompatible with global systems

It is of limited spatial coverage

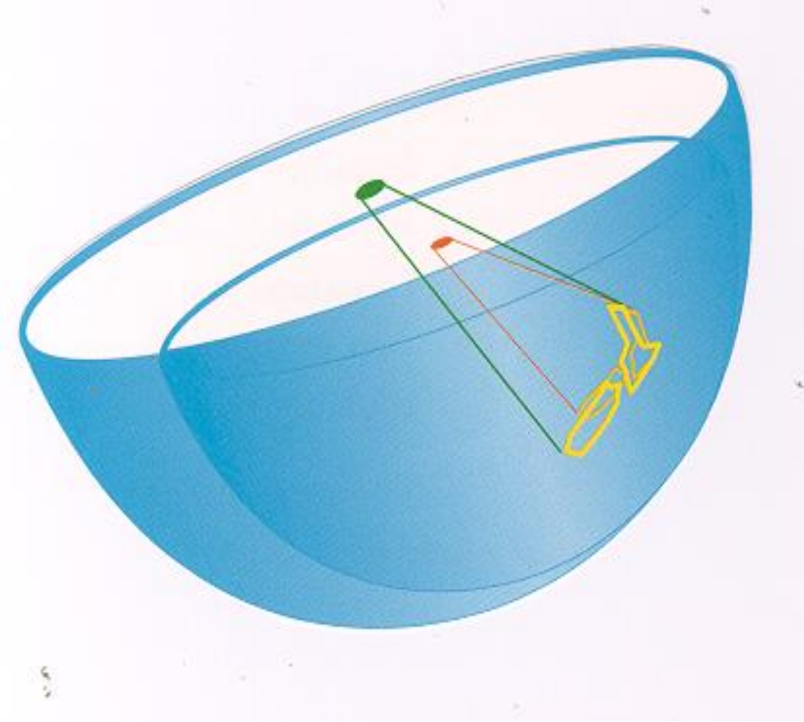
It is static



NZGD2000

1998 – NZ introduced NZGD2000 (ref epoch 1 Jan 2000)

- geocentric origin
- ITRF96 with epoch 2000.0 coordinates

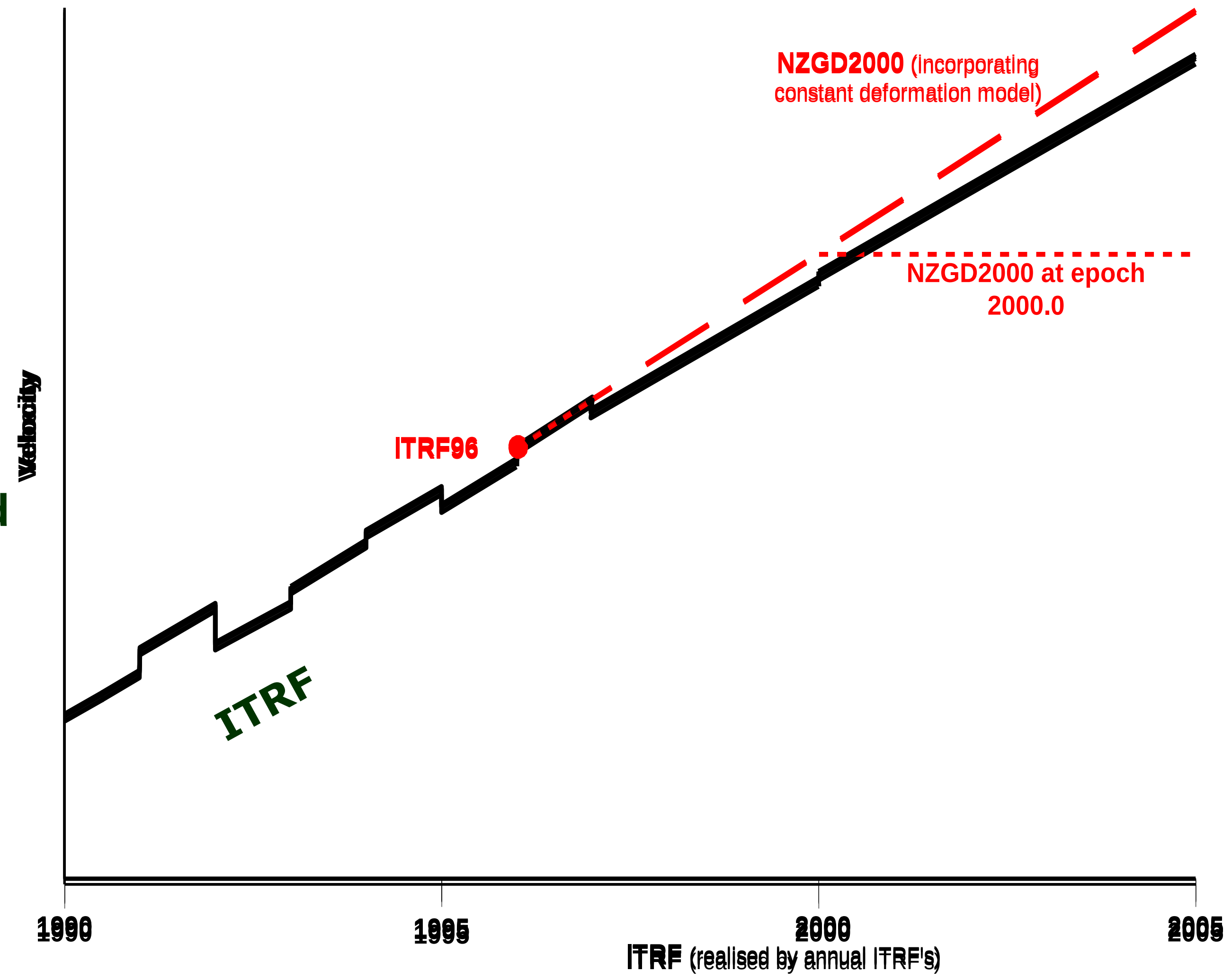


NZGD2000 - semi-dynamic datum

- generalised motion of points modelled using a deformation model

NZGD2000

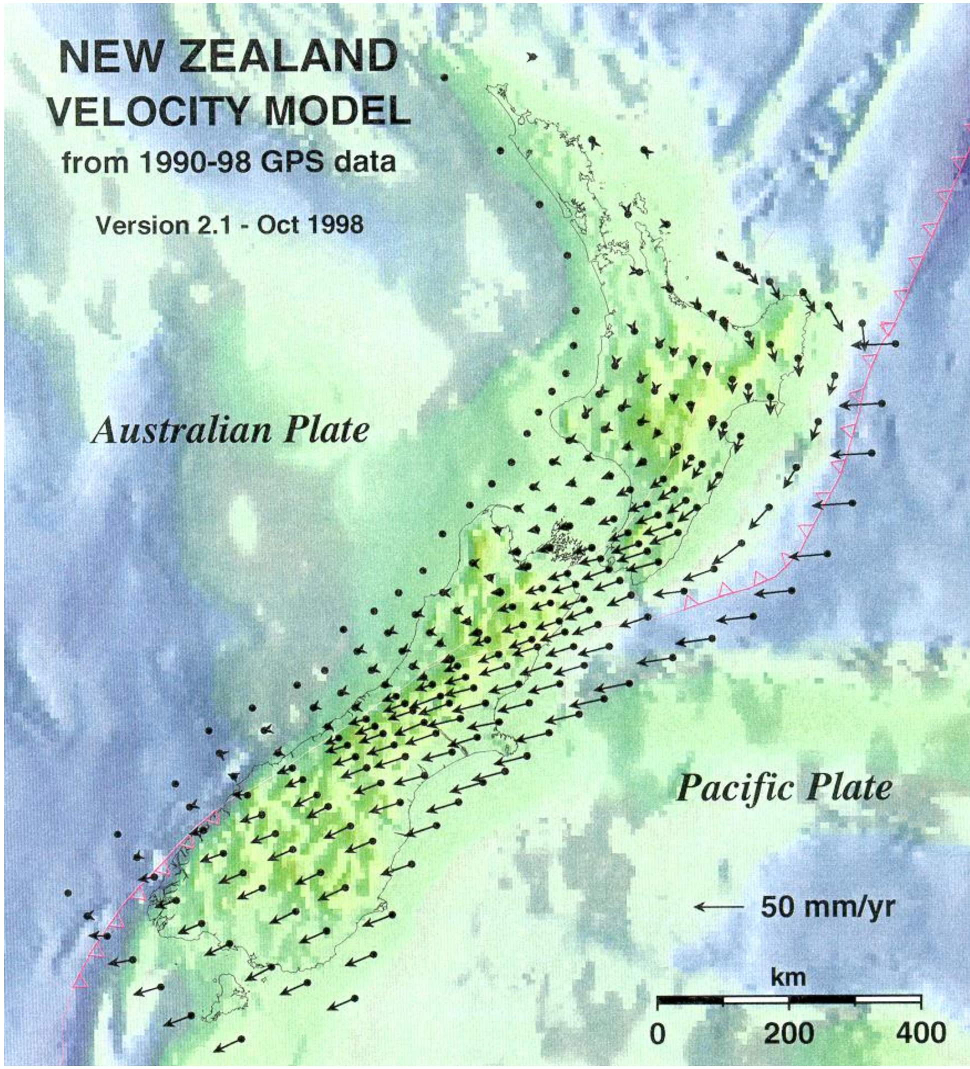
- Tied to ITRF96
- Generalised motion of points modelled using a constant velocity deformation model
- Epoch 2000 coordinates generated at 2000.0



NZGD2000

Semi-dynamic datum

- current deformation model has horizontal constant velocities only
- generated using repeat surveys between 1992 and 1998
- enables propagation of coordinates and observations between reference epoch and observation epoch
- for many uses has the **appearance of a static datum**



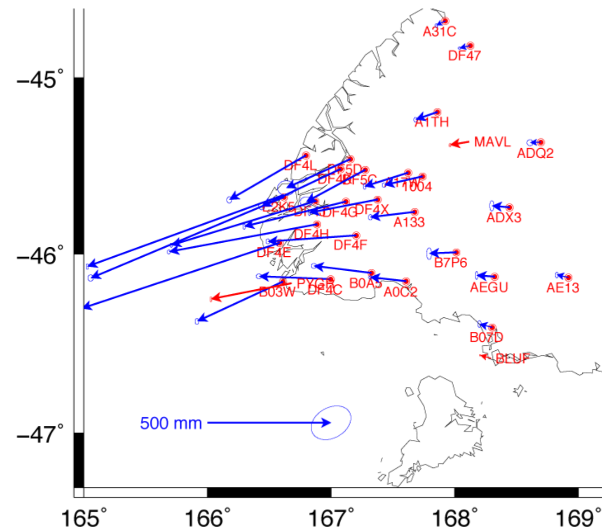
Where are we at?

What has gone well

- User Acceptance
- Implementation of the Deformation Model in LINZ
- Maintaining the Accuracy of Datum

Issues

- Managing the Deformation Model
- Accuracy of Deformation Model Versus CORS Real Time positions
- Managing the Spatial Alignment of the Cadastral System
- Misalignment of Readjusted Historic Geodetic Control with new Surveyed Geodetic Control



Future developments

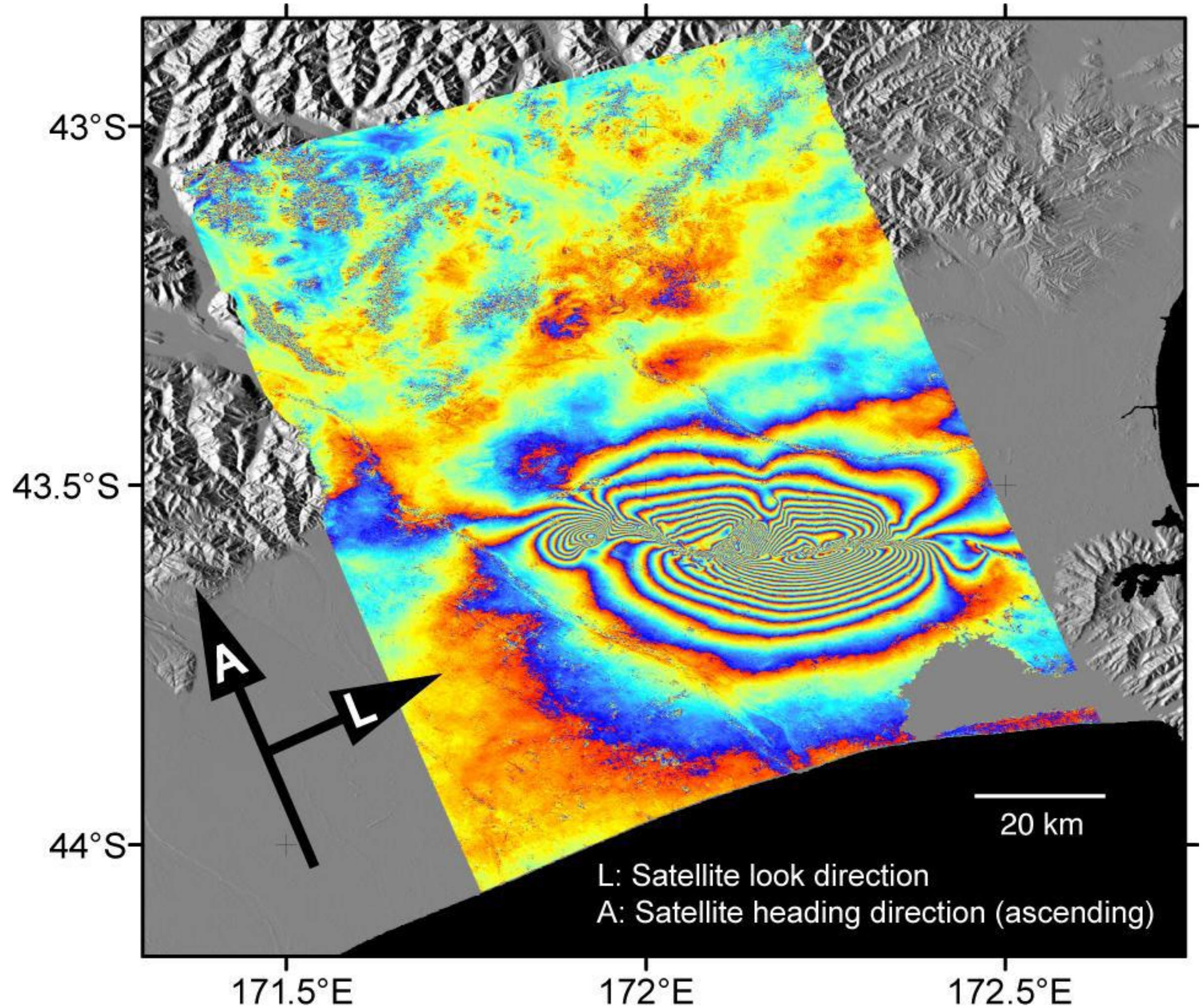
- Updating the Deformation Model
- Vertical Deformation Model
- CORS Real Time – Tools for Managing Coordinates
- Tie to the ITRF - Going Fully Dynamic?

Canterbury Earthquakes

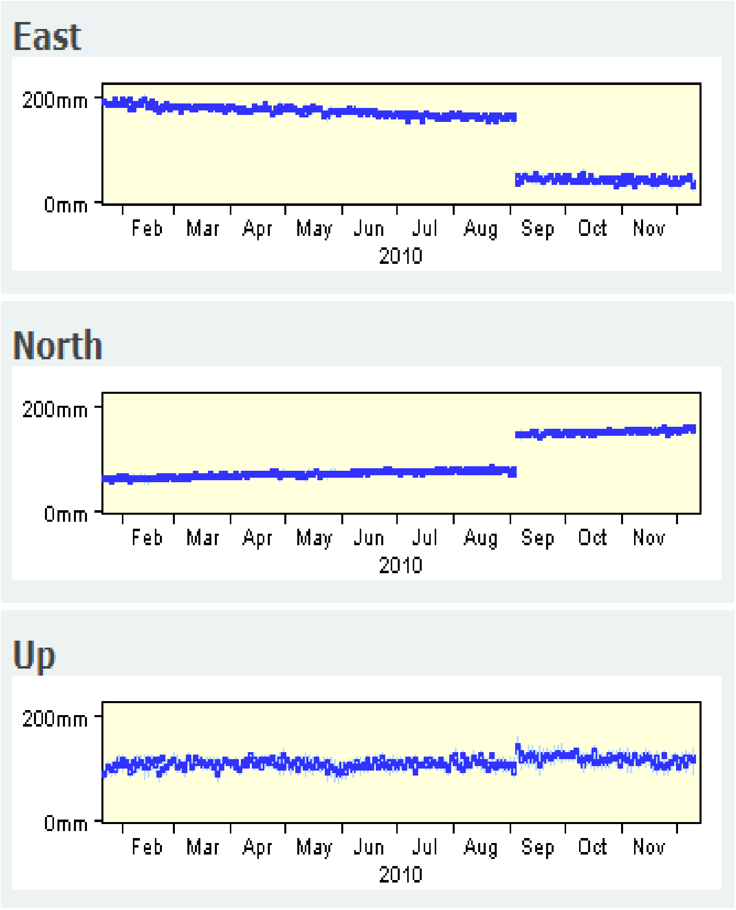
InSAR interference pattern as a result of the earthquake

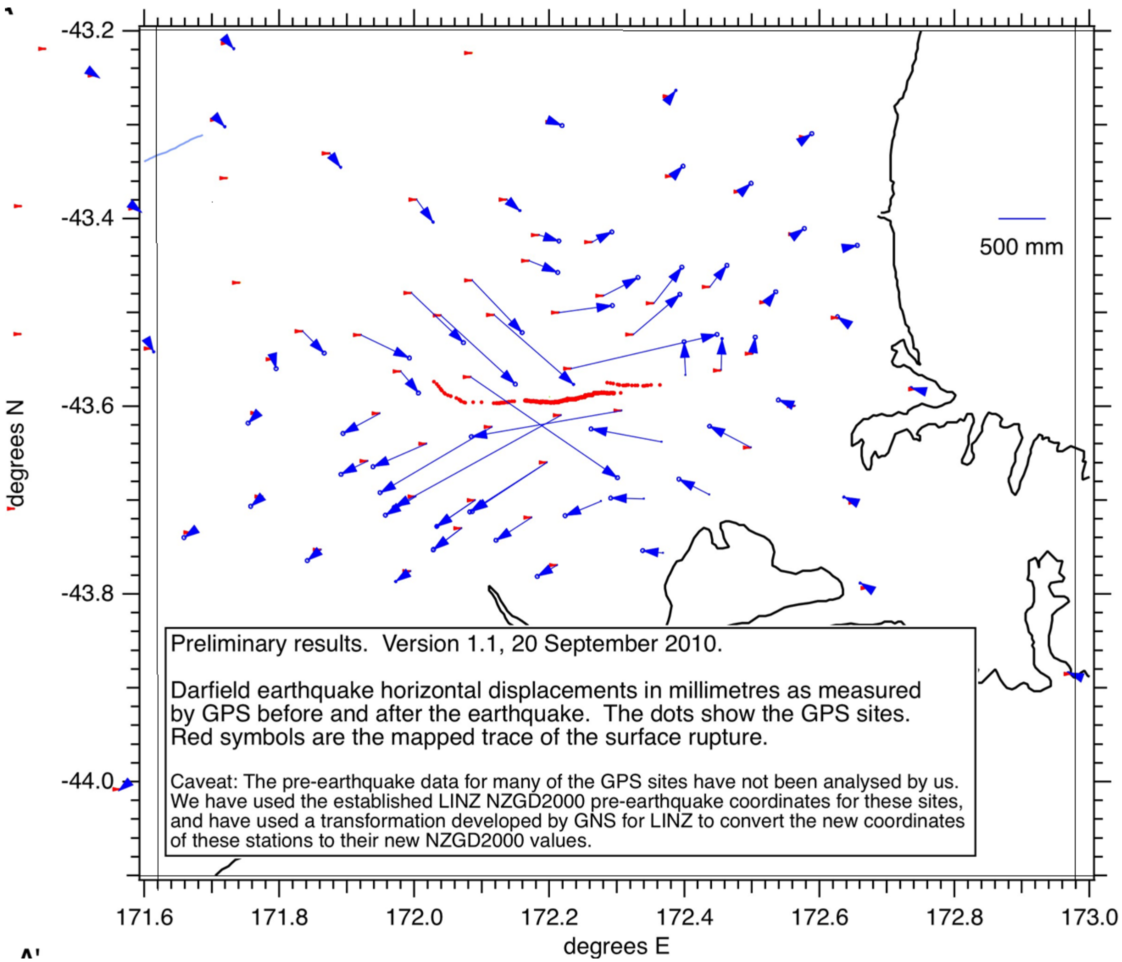
Each coloured fringe represents 1.5 cm of ground displacement in line-of-sight to the satellite

Incoherent regions indicate ground damage



Creating a patch – Canterbury earthquakes



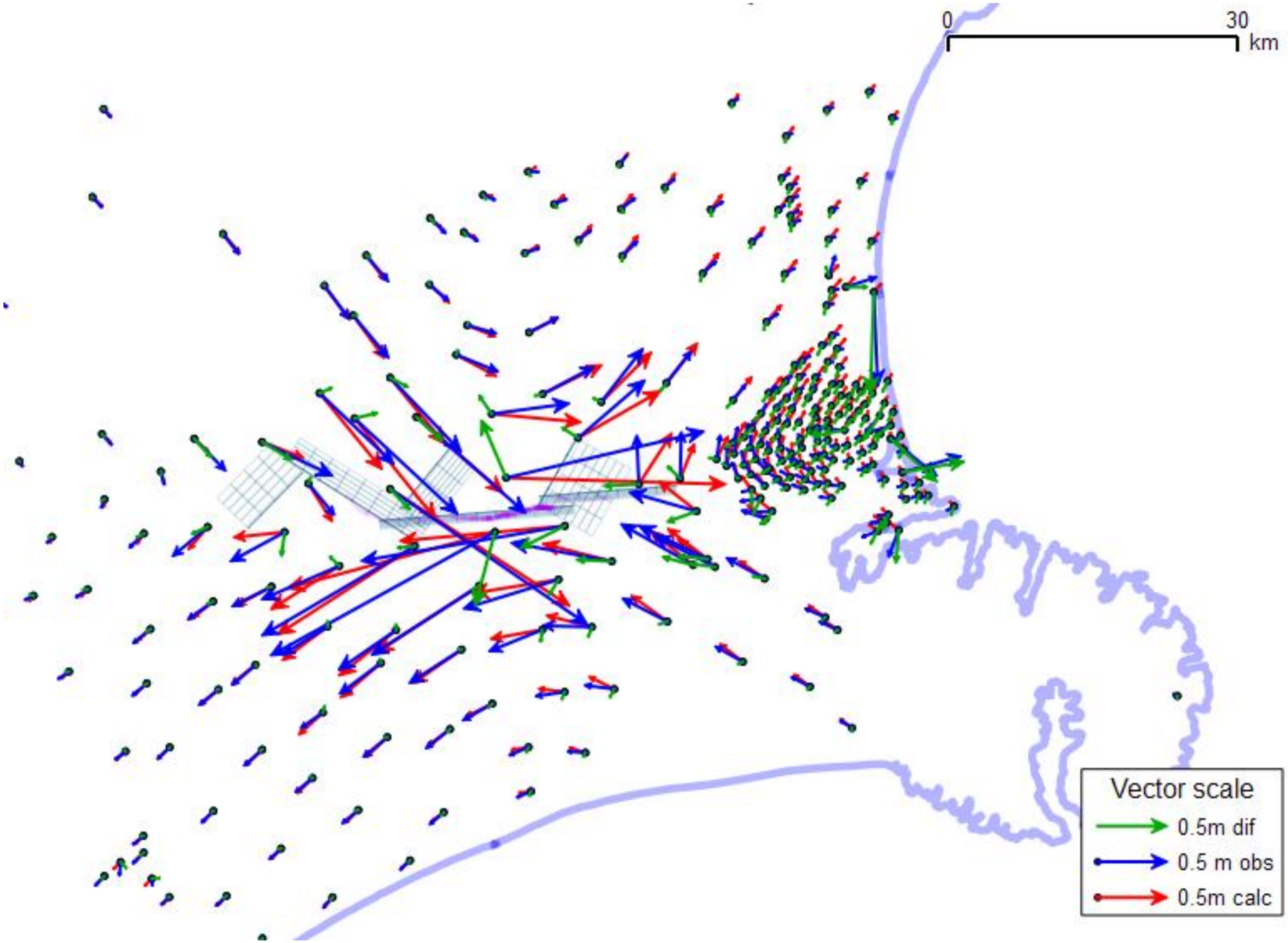


Impact on geodetic control and digital cadastre

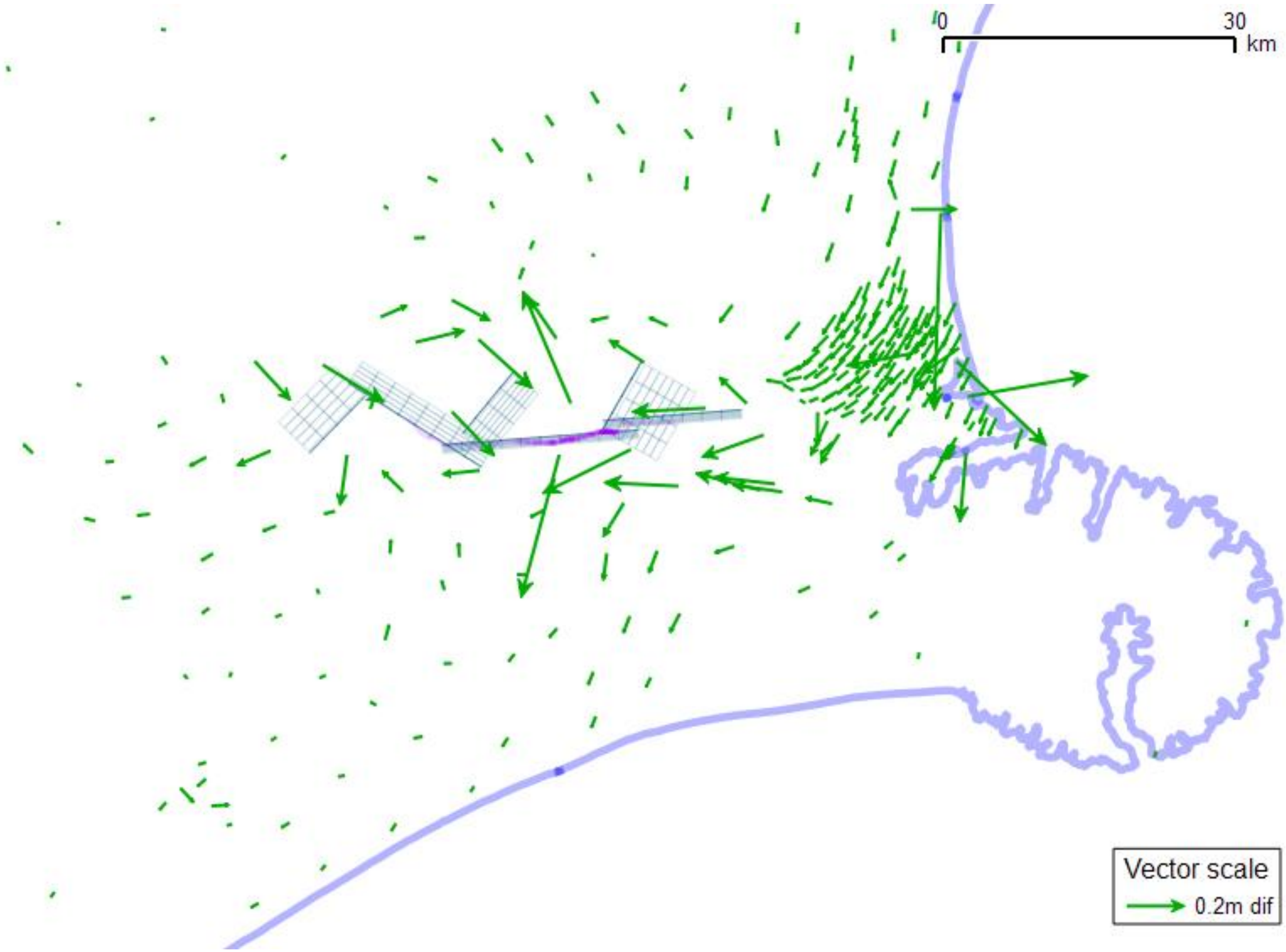
Range is based on the distance from the centre of the fault rupture.

Maximum Range (km)	Geodetic marks (order 5 or better)	Cadastral control (order 6 or better)	Total marks
0-20	223	4816	56835
20-40	1269	49538	565892
40-60	3176	28632	387606
60-80	673	3681	143593
80-100	487	2182	103995
Total	**5828**	**88849**	**1257921**

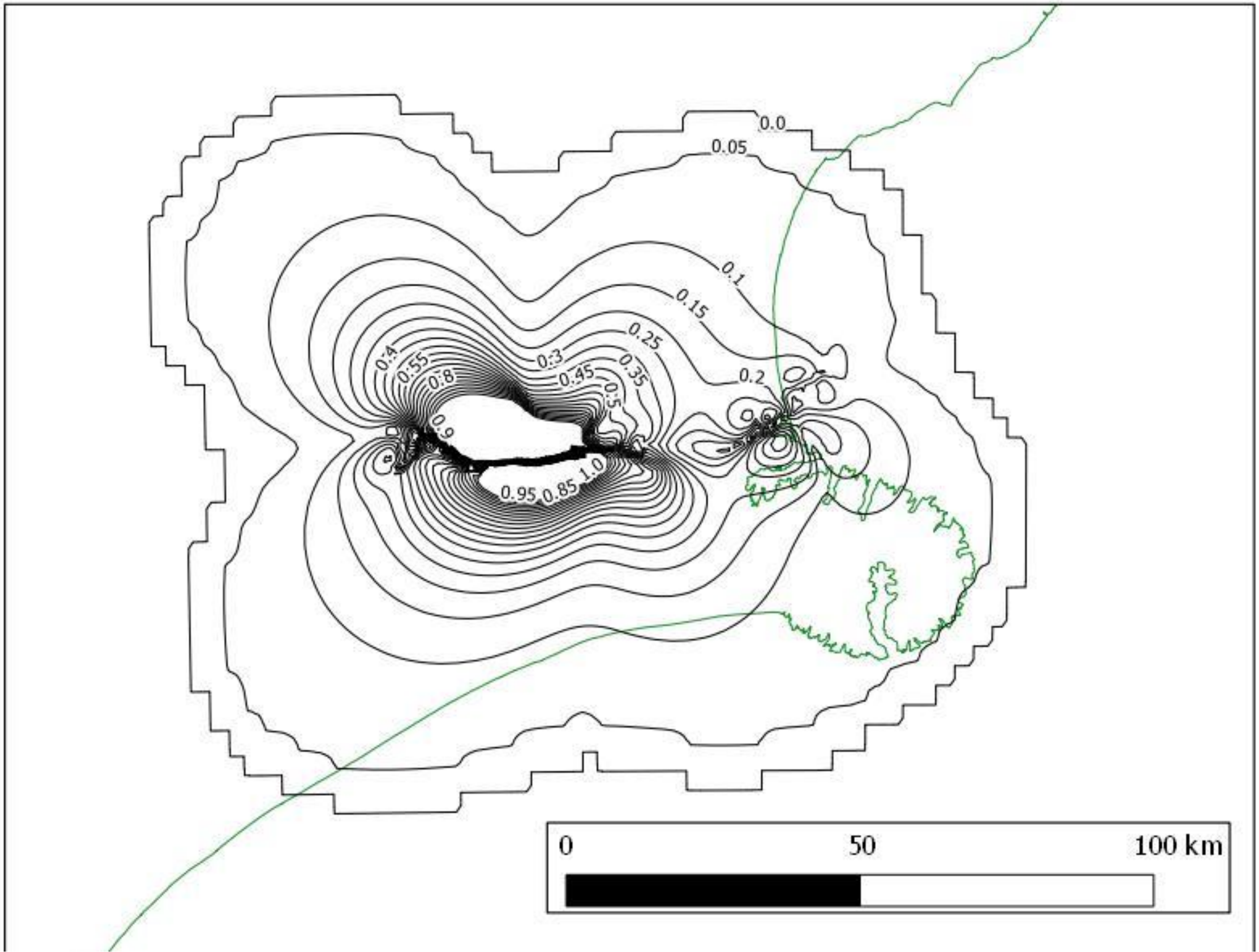
Model out the effects of the earthquake



Residuals



Extent of update



Summary

- The incorporation of a deformation model in NZGD2000 has enabled
  - the life of the datum to be lengthened
  - new observations to be integrated with old observations
  - the accuracy of the datum to be maintained
- But
  - how complex deformation events will be incorporated in the model have yet to be fully determined and resolved

Determining Coordinates in a National Datum from Absolute ITRF Positions: A New Zealand Case Study

Overview

- Transformation between reference frames using standard transformations
- Transformation between epochs using a velocity model
- Concepts illustrated through a worked example

Key Concepts

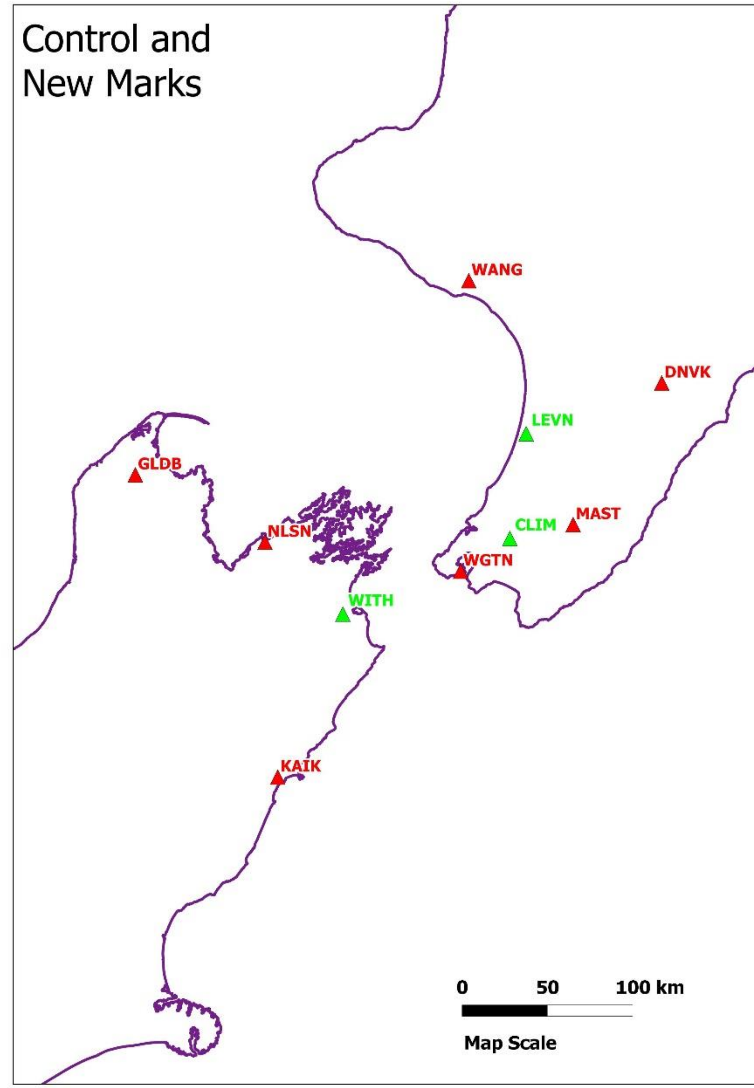
- Local, project-specific reference frame realizations can be made by the surveyor
- Incorporating velocities may be new, but the calculations are simple
- It is vital to check the accuracy of your realization
- A concise but clear description of how the coordinates were generated is needed

Why is this important?

- Getting precise coordinates in the latest ITRF realization has been greatly simplified through the provision of online GNSS processing services. These provide ITRF positions
- But most countries do not use the latest version of ITRF as their official datum
- So we need to be able to transform coordinates from ITRF to the national datum
- We could always just make relative connections to control provided by the national geodetic agency, but this is not always the most efficient method
- Both coordinates may be required: ITRF for maximum precision and global consistency and local coordinates to meet regulatory requirements and ensure consistency with local datasets

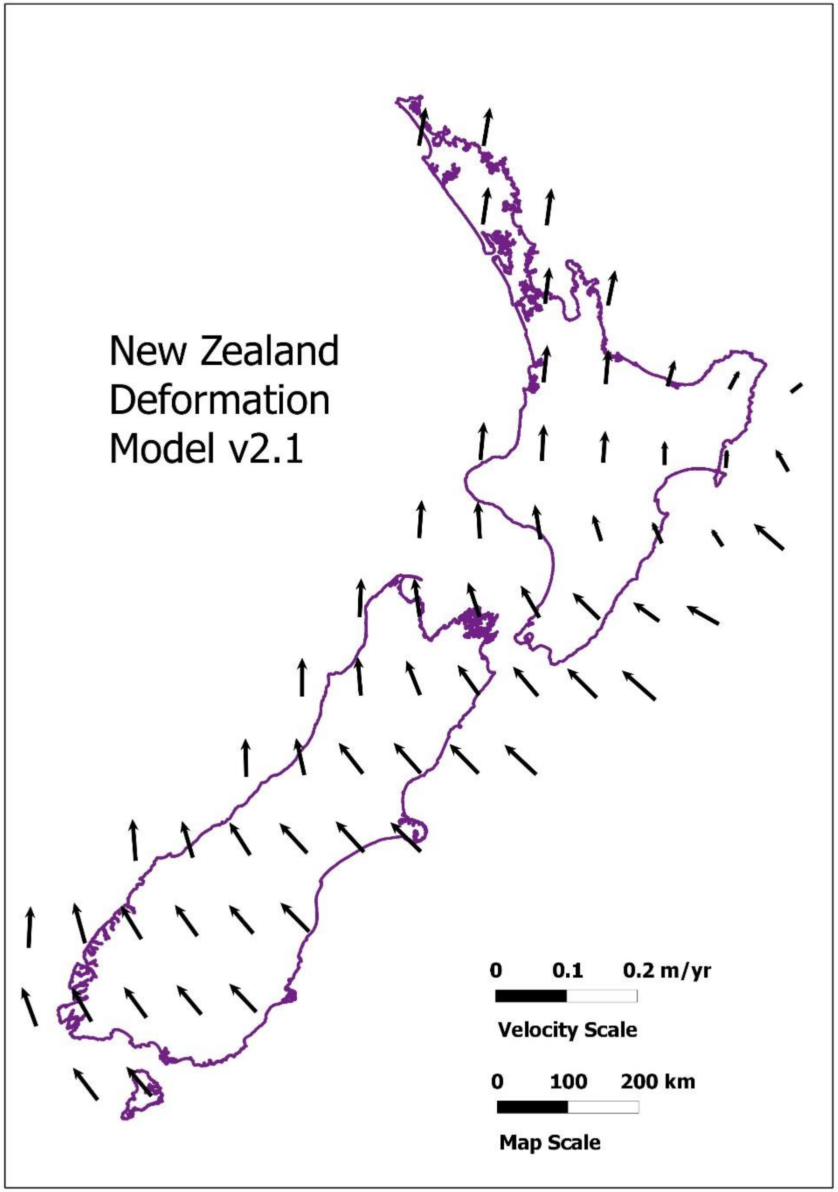
Scenario

- Client has requested control for a large project in New Zealand
- They are a global company, and hold all of their data in the latest ITRF realization. Therefore need ITRF2008 coordinates
- To meet regulatory requirements, data must also be provided in the official datum. Therefore need NZGD2000 coordinates
- Client also requires a means of transforming between the two sets of coordinates
- Seven control stations (GLDB, NLSN, KAIK, WGTN, MAST, DNVK, WANG)
- Three new stations (CLIM, LEVN, WITH)



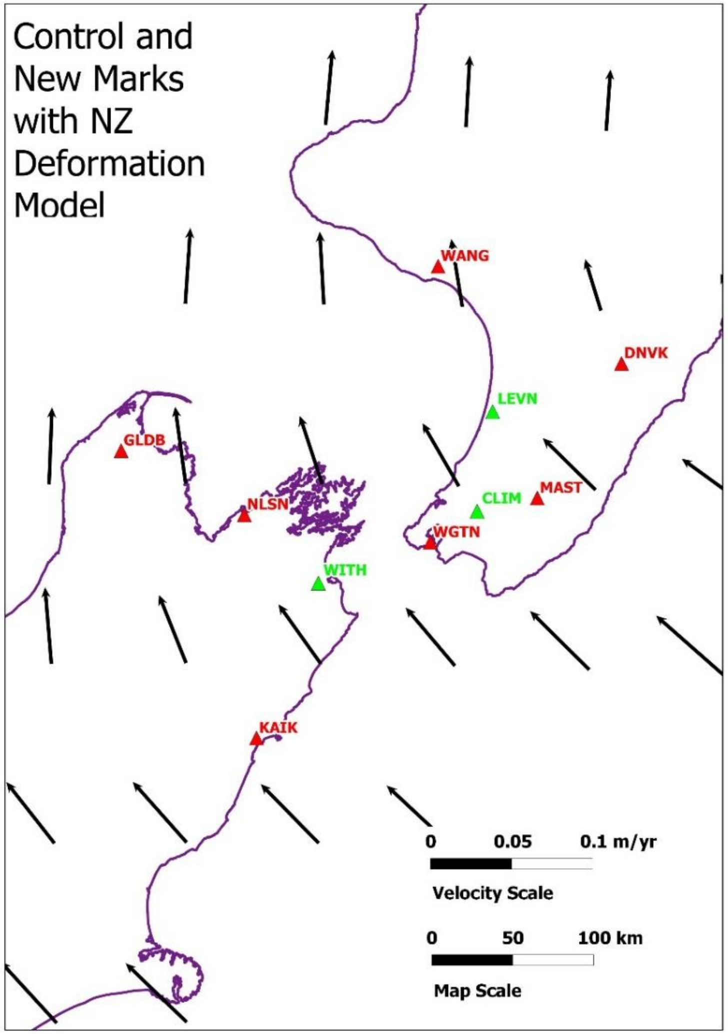
Background

- The official datum is New Zealand Geodetic Datum 2000 (NZGD2000)
- Defined as ITRF96 at epoch 2000.0
- New Zealand is at the boundary of the Australian and Pacific plates
- Even over small distances, marks can be moving at different velocities. Cannot assume a static Earth
- Includes a deformation model which can be used to generate coordinates at other epochs
- Official, highly accurate coordinates are published at CORS stations, and other passive marks



Deformation over Project Area

- Our project area is about 300km x 300km
- Station velocities vary significantly over this area



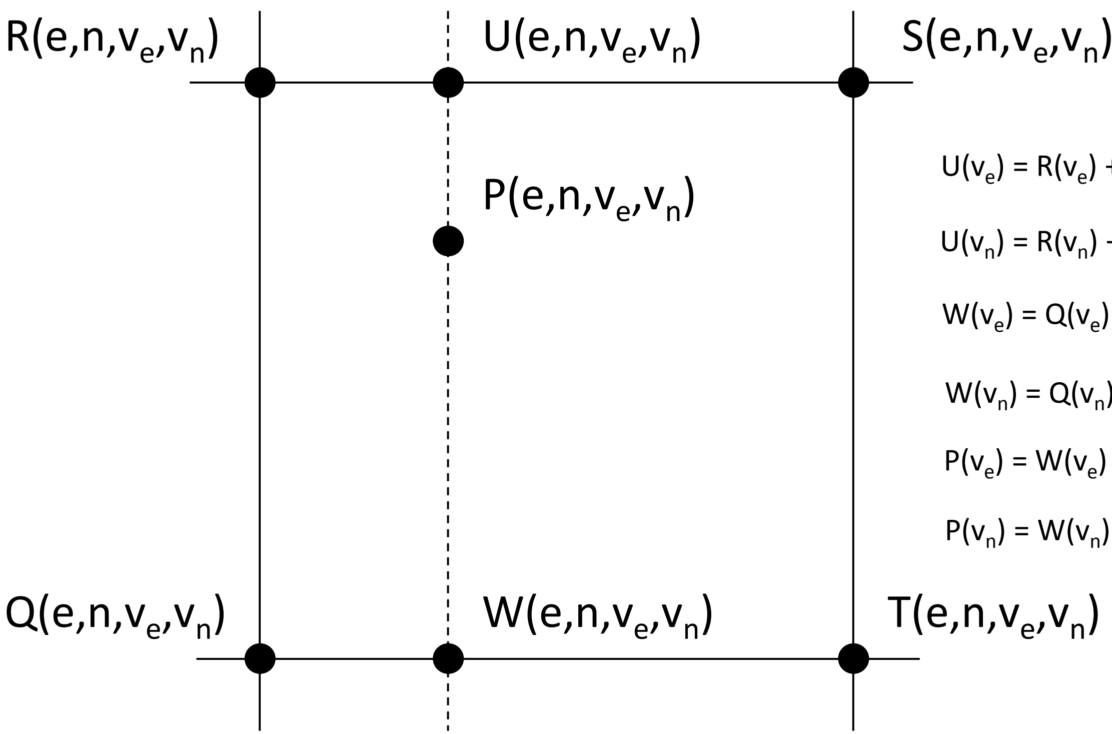
ITRF2008

- We do all our processing in the more accurate reference frame, and then transform to any other desired reference frame and epoch
- Generation of high precision ITRF coordinates usually requires scientific GNSS processing software, not used by most surveyors
- Therefore choose to use an online processing service (in this case JPL precise point positioning)
- This will give us ITRF2008 coordinates, in terms of the reference frame used by the IGS orbital products (IGS08).
- Process 24-hour sessions
- We end up with IGS08 coordinates at observation epoch, which is 2012 Julian Day 60 (2012.16)

Transforming Coordinates

- Throughout, we are working in Cartesian (geocentric) coordinates. Any other transformations, such as to a mapping projection, are made at the end
- Step 1: Identify stations at which coordinates are available in both the desired reference frames (ITRF and national datum)
- Step 2: Use velocities at each station to obtain coordinates at a common epoch in the two reference frames
- Step 3: Calculate *appropriate* transformation parameters, using least squares. This will usually be three translation/rotation parameters, or three translation/rotation parameters plus one scale parameter over small portions of the Earth's surface
- Step 4: Use the transformation parameters to convert coordinates between reference frames

Bilinear Interpolation



$$U(v_e) = R(v_e) + [(U(e) - R(e))/(S(e) - R(e))][S(v_e) - R(v_e)]$$

$$U(v_n) = R(v_n) + [(U(e) - R(e))/(S(e) - R(e))][S(v_n) - R(v_n)]$$

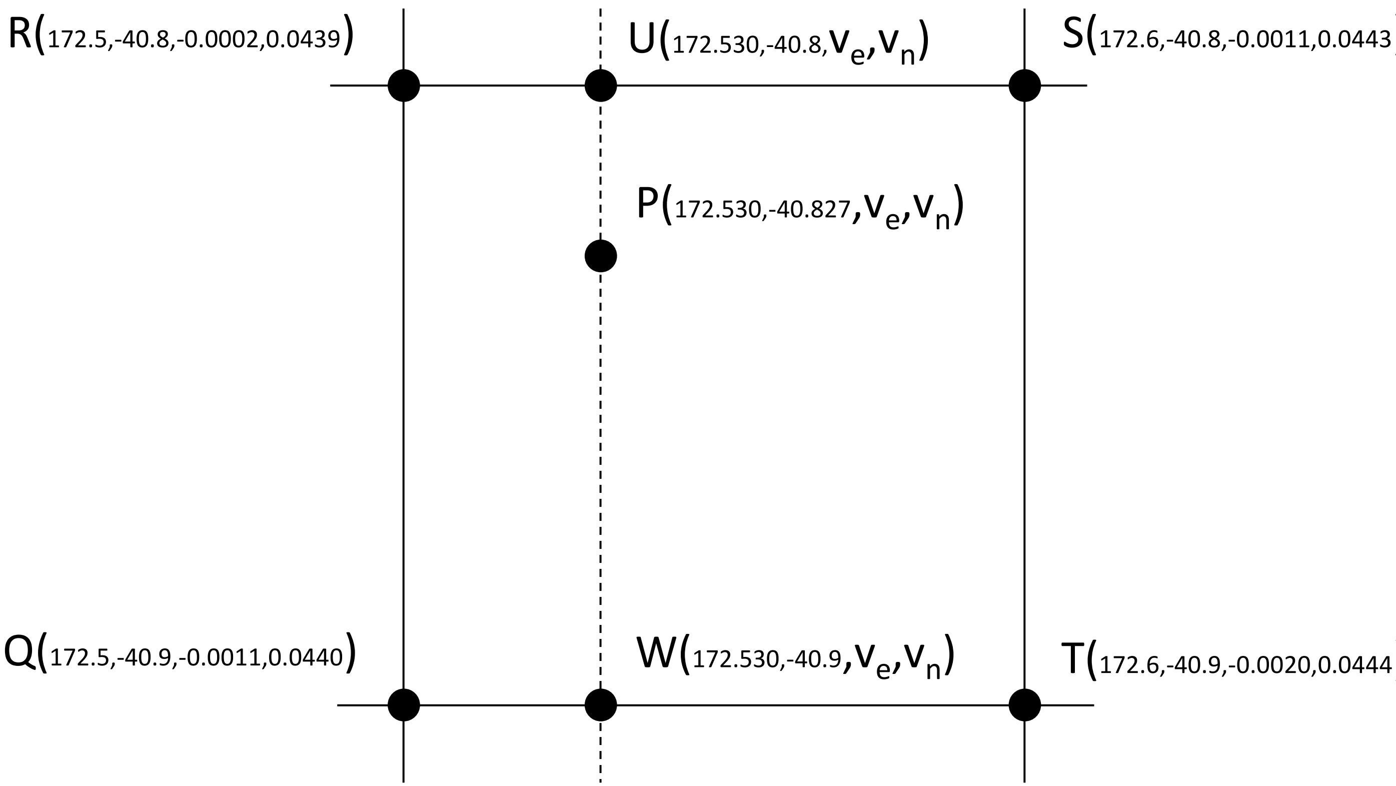
$$W(v_e) = Q(v_e) + [(W(e) - Q(e))/(T(e) - Q(e))][T(v_e) - Q(v_e)]$$

$$W(v_n) = Q(v_n) + [(W(e) - Q(e))/(T(e) - Q(e))][T(v_n) - Q(v_n)]$$

$$P(v_e) = W(v_e) + [(P(n) - W(n))/(U(n) - W(n))][U(v_e) - W(v_e)]$$

$$P(v_n) = W(v_n) + [(P(n) - W(n))/(U(n) - W(n))][U(v_n) - W(v_n)]$$

Calculating Velocity – Station GLDB



Calculating Velocity – Station GLDB

$U(v_e) = -0.0002 + [(172.530 – 172.5)/(172.6 – 172.5)][-0.0011 – -0.0002] = -0.0005$

$U(v_n) = 0.0439 + [(172.530 – 172.5)/(172.6 – 172.5)][0.0443 – 0.0439] = 0.0440$

$W(v_e) = -0.0011 + [(172.530 – 172.5)/(172.6 – 172.5)][-0.0020 – -0.0011] = -0.0013$

$W(v_n) = 0.0440 + [(172.530 – 172.5)/(172.6 – 172.5)][0.0444 – 0.0440] = 0.0441$

$P(v_e) = -0.0013 + [(-40.827– -40.9)/(-40.8 – -40.9)][-0.0005 – -0.0013] = -0.0007$

$P(v_n) = 0.0441 + [(-40.827– -40.9)/(-40.8 – -40.9)][0.0440 – 0.0441] = 0.0441$

Transforming Velocities to Cartesian Reference Frame

- Recall that we are always working in Cartesian (XYZ) coordinates, so need XYZ velocities. Call this column vector $\mathbf{v}_{XYZ}$
- But the velocity model is topocentric (ENU). Call this column vector $\mathbf{v}_{ENU}$
- We can convert between the two using the geocentric to topocentric rotation matrix, $\mathbf{R}_{gt}$, for the point's latitude (ϕ) and longitude (λ)
- $\mathbf{v}_{ENU} = \mathbf{R}_{gt}\mathbf{v}_{XYZ}$
- $\mathbf{v}_{XYZ} = \mathbf{R}_{gt}^{T}\mathbf{v}_{ENU}$

$$R_{gt} = \begin{bmatrix} -\sin\lambda & \cos\lambda & 0 \\ -\sin\phi\cos\lambda & -\sin\phi\sin\lambda & \cos\phi \\ \cos\phi\cos\lambda & \cos\phi\sin\lambda & \sin\phi \end{bmatrix}$$

Transforming Velocities to Cartesian Reference Frame – Station GLDB

- $\mathbf{v}_{XYZ} = \mathbf{R}_{gt}^{T}\mathbf{v}_{ENU}$

$$\begin{bmatrix} v_x \\ v_y \\ v_z \end{bmatrix} = \begin{bmatrix} -0.130 & -0.992 & 0 \\ -0.648 & 0.085 & 0.757 \\ -0.750 & 0.098 & -0.654 \end{bmatrix}^T \begin{bmatrix} -0.0007 \\ 0.0441 \\ 0 \end{bmatrix} = \begin{bmatrix} -0.0285 \\ 0.0045 \\ 0.0333 \end{bmatrix}$$

Calculating NZGD2000 Epoch 2012.16 Coordinates – Station GLDB

- $\mathbf{x}_{\text{NZGD Epoch 2012.16}} = \mathbf{x}_{\text{NZGD2000 Epoch 2000.0}} + 12.16\mathbf{v}_{\text{XYZ}}$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}_{201216} = \begin{bmatrix} -4792405.831 \\ 628416.781 \\ -4148068.669 \end{bmatrix} + 12.16 \begin{bmatrix} -0.0285 \\ 0.0045 \\ 0.0333 \end{bmatrix} = \begin{bmatrix} -4792406.177 \\ 628416.835 \\ -4148068.263 \end{bmatrix}$$

Calculating Transformation Parameters

- Use least squares to obtain the best solution, as we have more observations than parameters
- Functional model: $\mathbf{At} = \mathbf{b}$, where $\mathbf{A}$ is the design matrix, $\mathbf{b}$ = Calculated (IT96) minus observed (IGS08) and $\mathbf{t}$ is the matrix of unknown transformation parameters
- Stochastic model: $\mathbf{W} = \mathbf{I}$, in this case we choose to weight all coordinates equally
- So $\mathbf{t} = (\mathbf{A}^T\mathbf{A})^{-1}\mathbf{A}^T\mathbf{b}$, the standard least squares solution
- And $\mathrm{Cov}(\mathbf{t}) = \sigma_0^2(\mathbf{A}^T\mathbf{A})^{-1}$
- The Aposteriori Standard Error of Unit Weight is $\sigma_0^{2\,=}\,(\mathbf{A}^T\mathbf{t}-\mathbf{b})^T(\mathbf{A}^T\mathbf{t}-\mathbf{b})$/(degrees of freedom)
- This is a linear problem, so no need to iterate
- Note: if you wish to weight your coordinates: $\mathbf{t} = (\mathbf{A}^T\mathbf{W}\mathbf{A})^{-1}\mathbf{A}^T\mathbf{W}\mathbf{b}$

$$
\begin{array}{ll}
GLDB & x \\
 & y \\
 & z \\
NLSN & x \\
 & y \\
 & z \\
KAIK & x \\
 & y \\
 & z \\
WGTN & x \\
 & y \\
 & z \\
MAST & x \\
 & y \\
 & z \\
DNVK & x \\
 & y \\
 & z \\
WANG & x \\
 & y \\
 & z
\end{array}
\qquad
A = \begin{bmatrix}
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1 \\
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1 \\
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1 \\
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1 \\
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1 \\
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1 \\
1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1
\end{bmatrix}
\quad
b = \begin{bmatrix}
-4792406.177 \\
628416.835 \\
-4148068.263 \\
-4775888.435 \\
549740.211 \\
-4177981.109 \\
-4685479.521 \\
531055.197 \\
-4280819.034 \\
-4777269.652 \\
434270.387 \\
-4189484.267 \\
-4801933.943 \\
370789.222 \\
-4167752.305 \\
-4860760.939 \\
325692.752 \\
-4103646.312 \\
-4888073.52 \\
443004.771 \\
-4060015.325
\end{bmatrix}
-
\begin{bmatrix}
-4792406.117 \\
628416.851 \\
-4148068.23 \\
-4775888.398 \\
549740.2 \\
-4177981.061 \\
-4685479.471 \\
531055.245 \\
-4280819.009 \\
-4777269.602 \\
434270.406 \\
-4189484.221 \\
-4801933.888 \\
370789.24 \\
-4167752.257 \\
-4860760.892 \\
325692.771 \\
-4103646.255 \\
-4888073.493 \\
443004.775 \\
-4060015.31
\end{bmatrix}
=
\begin{bmatrix}
-0.06 \\
-0.016 \\
-0.033 \\
-0.037 \\
0.011 \\
-0.048 \\
-0.05 \\
-0.048 \\
-0.025 \\
-0.05 \\
-0.019 \\
-0.046 \\
-0.055 \\
-0.018 \\
-0.048 \\
-0.047 \\
-0.019 \\
-0.057 \\
-0.027 \\
-0.004 \\
-0.015
\end{bmatrix}
$$

$$
Cov(X) = \begin{bmatrix}
3.22\times10^{-5} & 0 & 0 \\
0 & 3.22\times10^{-5} & 0 \\
0 & 0 & 3.22\times10^{-5}
\end{bmatrix}
$$

Three Parameter Transformation Results

- SEUW = 0.015 m
- t_x = -0.046 ± 0.006 m
- t_y = -0.016 ± 0.006 m
- t_z = -0.039 ± 0.006 m
- Note: In this case least squares simply gives us the average of the coordinate differences, so we could have avoided the matrix algebra, but would not get the precision information so easily

Four Parameter Transformation Results

- SEUW = 0.015 m
- $t_x = -0.103 \pm 0.211$ m
- $t_y = -0.011 \pm 0.021$ m
- $t_z = -0.088 \pm 0.183$ m
- $s = -1.19 \times 10^{-8} \pm 4.40 \times 10^{-8}$
- None of the parameters is significant, so this is not the best transformation

[ ]

Calculate IT96 Epoch 2012.16 for CLIM

- $\mathbf{x}_{\text{NZGD Epoch 2012.16}} = \mathbf{x}_{\text{IGS08 Epoch 2012.16}} + \mathbf{t}$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}_{NZGD2000\ 201216} = \begin{bmatrix} -4793404.120 \\ 407108.010 \\ -4175081.520 \end{bmatrix} + \begin{bmatrix} -0.046 \\ -0.016 \\ -0.039 \end{bmatrix} = \begin{bmatrix} -4793404.167 \\ 407107.994 \\ -4175081.559 \end{bmatrix}$$

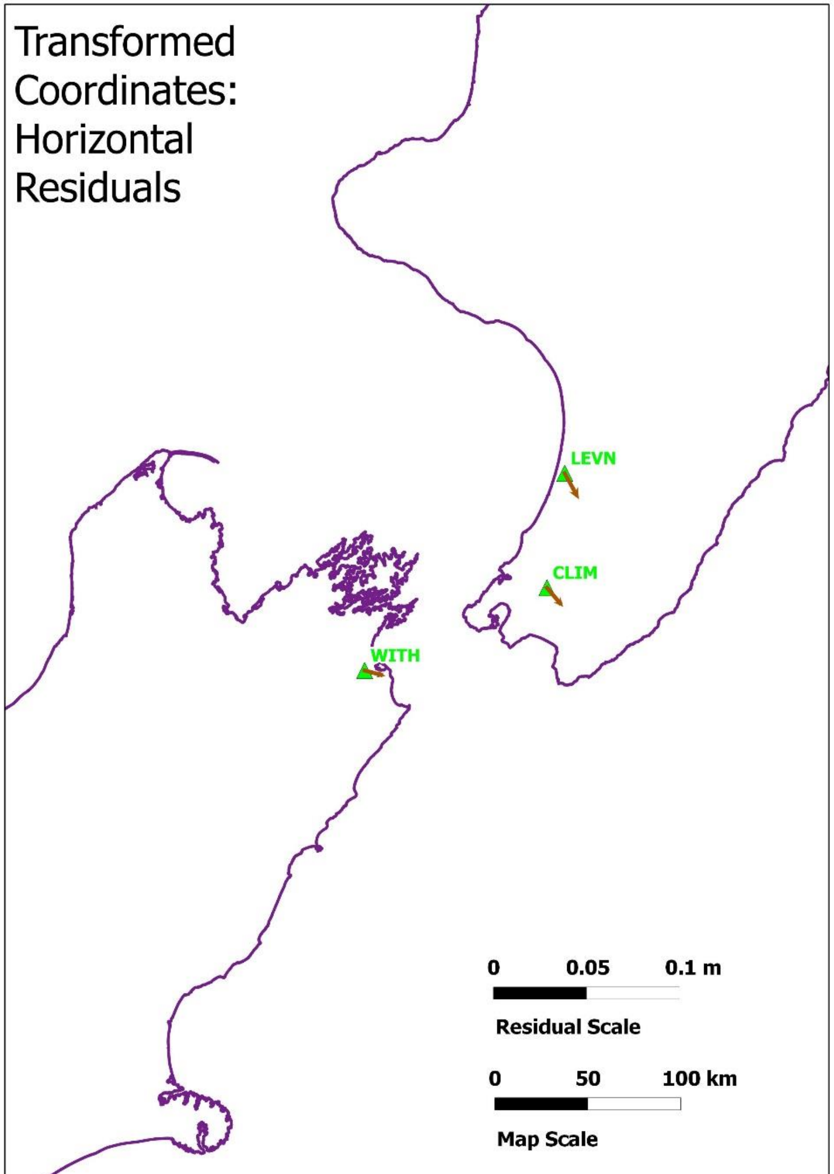
Calculate IT96 Epoch 2000 for CLIM

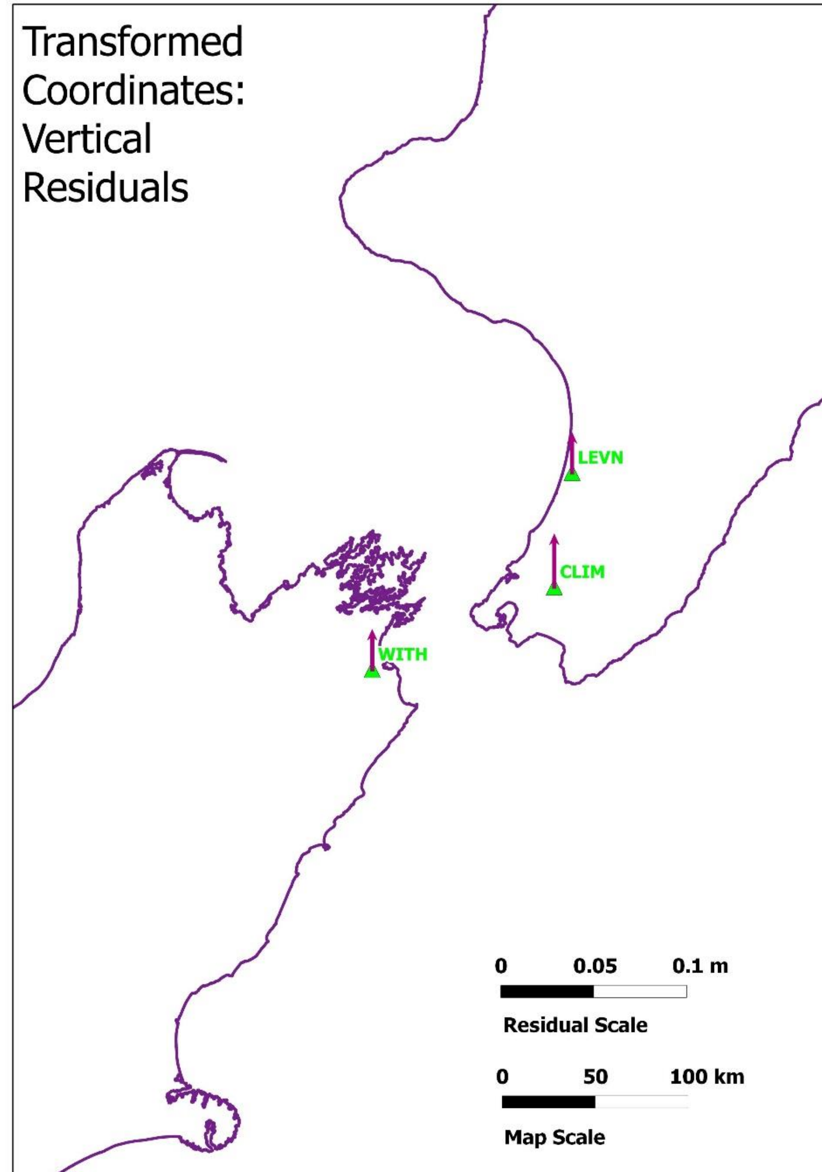
- $\mathbf{x}_{\text{NZGD Epoch 2000}} = \mathbf{x}_{\text{NZGD2000 Epoch 2012.16}} - 12.16\mathbf{v}_{xyz}$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}_{NZGD2000} = \begin{bmatrix} -4793404.167 \\ 407107.994 \\ -4175081.559 \end{bmatrix} - 12.16 \begin{bmatrix} -0.0196 \\ 0.0277 \\ 0.0250 \end{bmatrix} = \begin{bmatrix} -4793403.928 \\ 407107.657 \\ -4175081.864 \end{bmatrix}$$

Calculate IT96 Epoch 2000 for CLIM, LEVN, WITH

Station	IGS08 Epoch 2012.16 (XYZ)	Velocity (ENU)	NZGD2000 Epoch 2000.0 (observed)	NZGD2000 Epoch 2000.0 (GDB)	Difference (ENU)
CLIM	-4793404.120	-0.026	-4793403.928	-4793403.914	0.007
	407108.010	0.0333	407107.657	407107.663	-0.008
	-4175081.5204	0	-4175081.864	-4175081.841	0.025
LEVN	-4833775.0621	-0.0164	-4833774.861	-4833774.854	0.006
	402451.2374	0.0335	402451	402451.006	-0.011
	-4127913.8068	0	-4127914.155	-4127914.134	0.018
WITH	-4753506.3677	-0.0195	-4753506.156	-4753506.143	0.009
	500939.4145	0.0352	500939.133	500939.14	-0.002
	-4209496.456	0	-4209496.815	-4209496.801	0.018


Transformed Coordinates: Horizontal Residuals
LEVN
CLIM
WITH
0 0.05 0.1 m
Residual Scale
0 50 100 km
Map Scale


Transformed Coordinates: Vertical Residuals
LEVN
CLIM
WITH
0 0.05 0.1 m
Residual Scale
0 50 100 km
Map Scale

Summary

- Absolute positioning is readily available, and its use will increase
- These positions are in terms of the satellite orbit reference frame (latest IGS realization of current ITRF)
- Software to convert to a local reference frame (datum) may not exist, or may need to be tested
- This conversion can be done by the surveyor using a spreadsheet and the procedure outlined in this presentation

Questions and References

- http://apps.gdgps.net/ (JPL PPP service)
- http://apps.linz.govt.nz/gdb/index.aspx (LINZ Geodetic Database)

- For any questions please contact:

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