ITRF Transformations in Deforming Zones to Support CORS-NRTK Applications

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Never Stand Still

NRTK in deforming zones – The problem

NRTK requires high precision CORS coordinates (LU < 15 mm) in order to correctly model biases (e.g. troposheric, ionospheric) and orbit errors

Only achievable in tectonically active regions if near real-time (kinematic or dynamic) ITRF or IGS reference frame used for CORS.

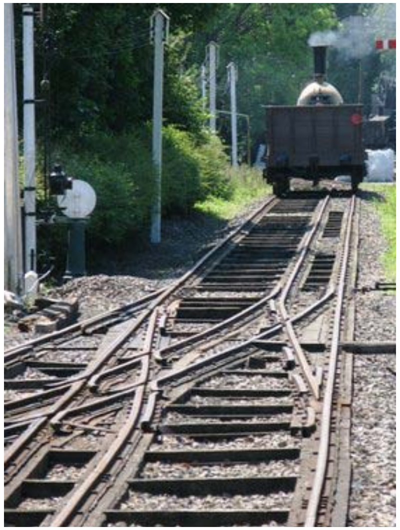
BUT

Kinematic ITRF isn't a practical working datum for NRTK users

Very difficult to harmoniously integrate surveys done at different times (e.g. engineering surveys, cadastral/DCDB, 3D laser scans, LiDAR, GIS)

e.g. between 700 mm difference between 2002 and 2012 due to movement of Australian tectonic plate

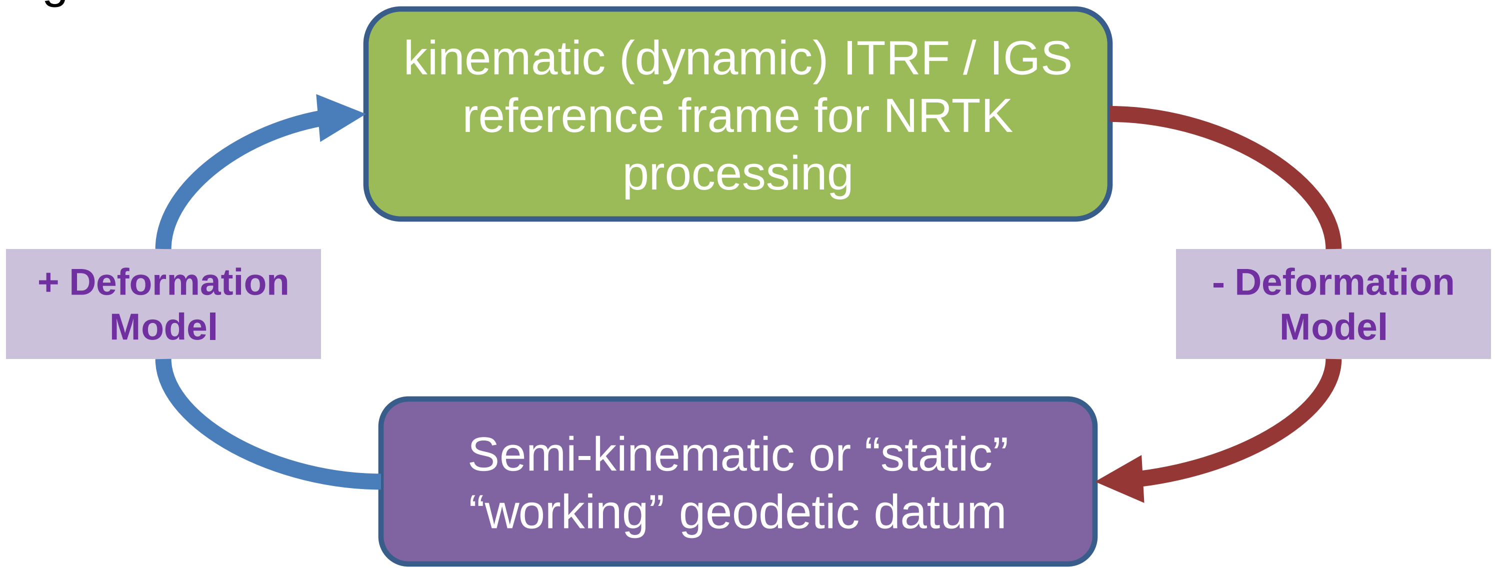
The classic "Standard rail gauge / train wreck problem"



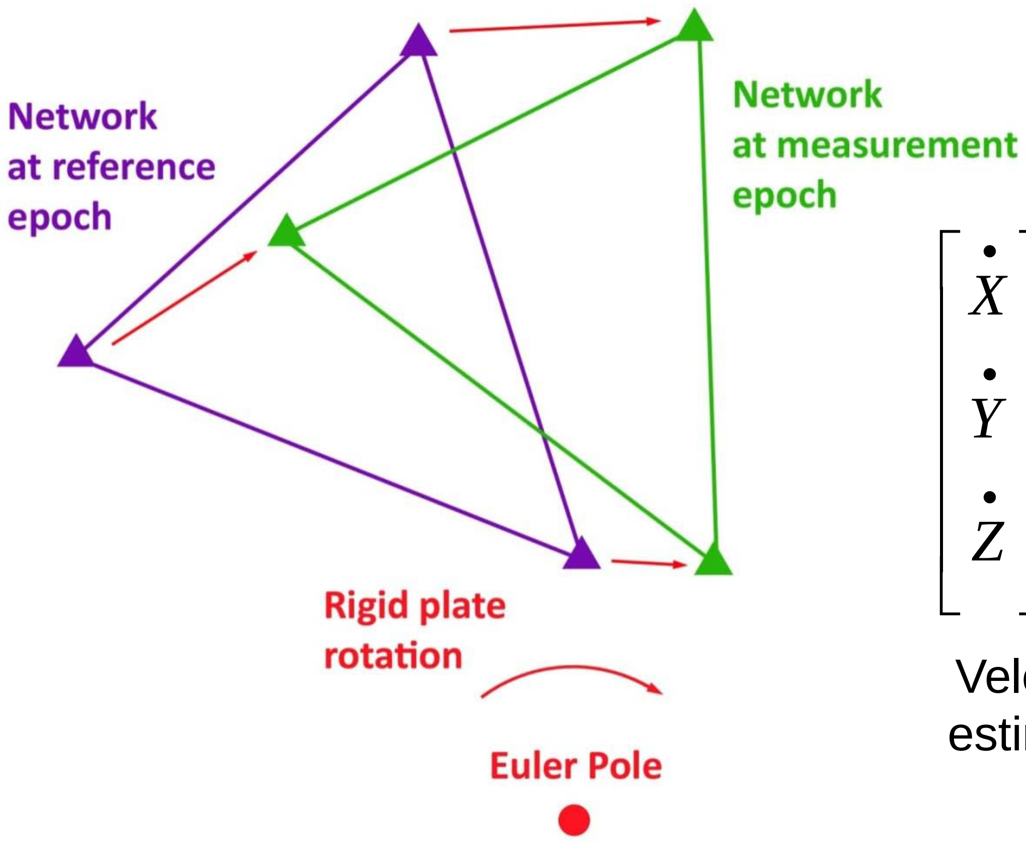
NRTK in deforming zones – A solution

Kinematic (dynamic) ITRF and IGS RF coordinates can be transformed to a working "static" geodetic datum using a robust deformation model

Best of both worlds: The complexity of global and local deformation modelling is handled by the NRTK server and software. End users do not "see" changes



Rigid plate deformation of CORS-NRTK

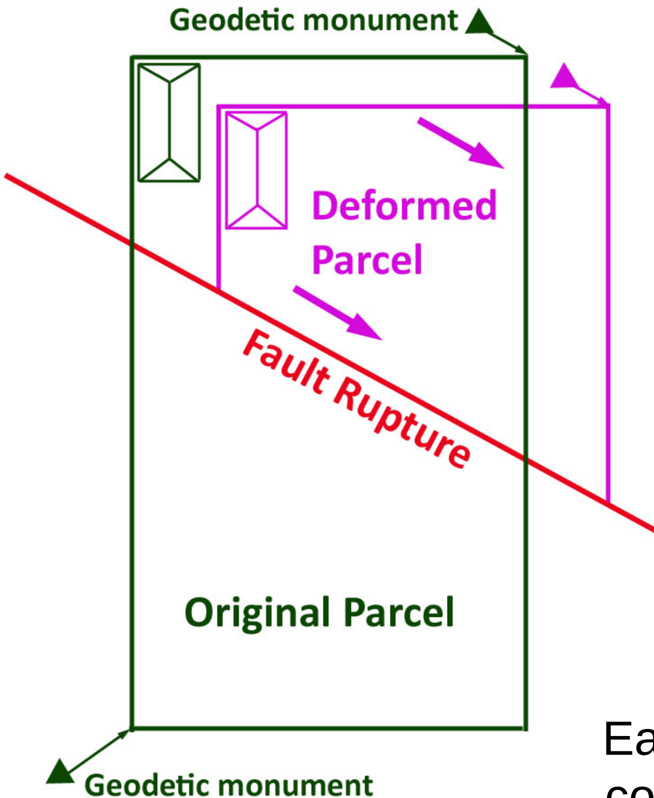


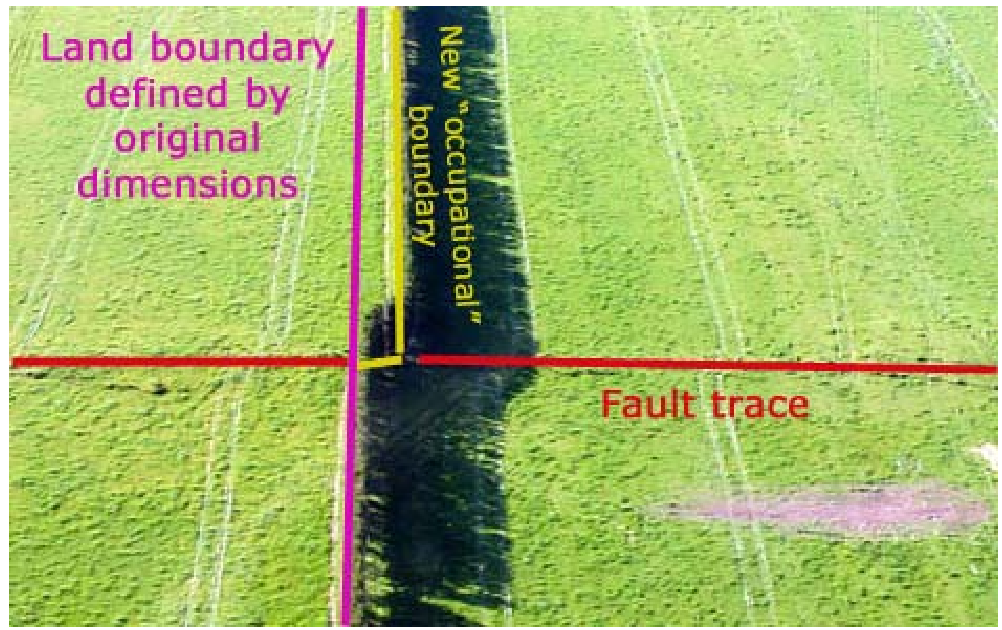
$$\begin{bmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{bmatrix} = \begin{bmatrix} \Omega_Y Z - \Omega_Z Y \\ \Omega_Z X - \Omega_X Z \\ \Omega_X Y - \Omega_Y X \end{bmatrix} \bullet 1\text{E-6}$$

Velocity and position can be estimated from rigid plate model (Ω_X, Ω_Y, Ω_Z)

or by 14 parameter transformation

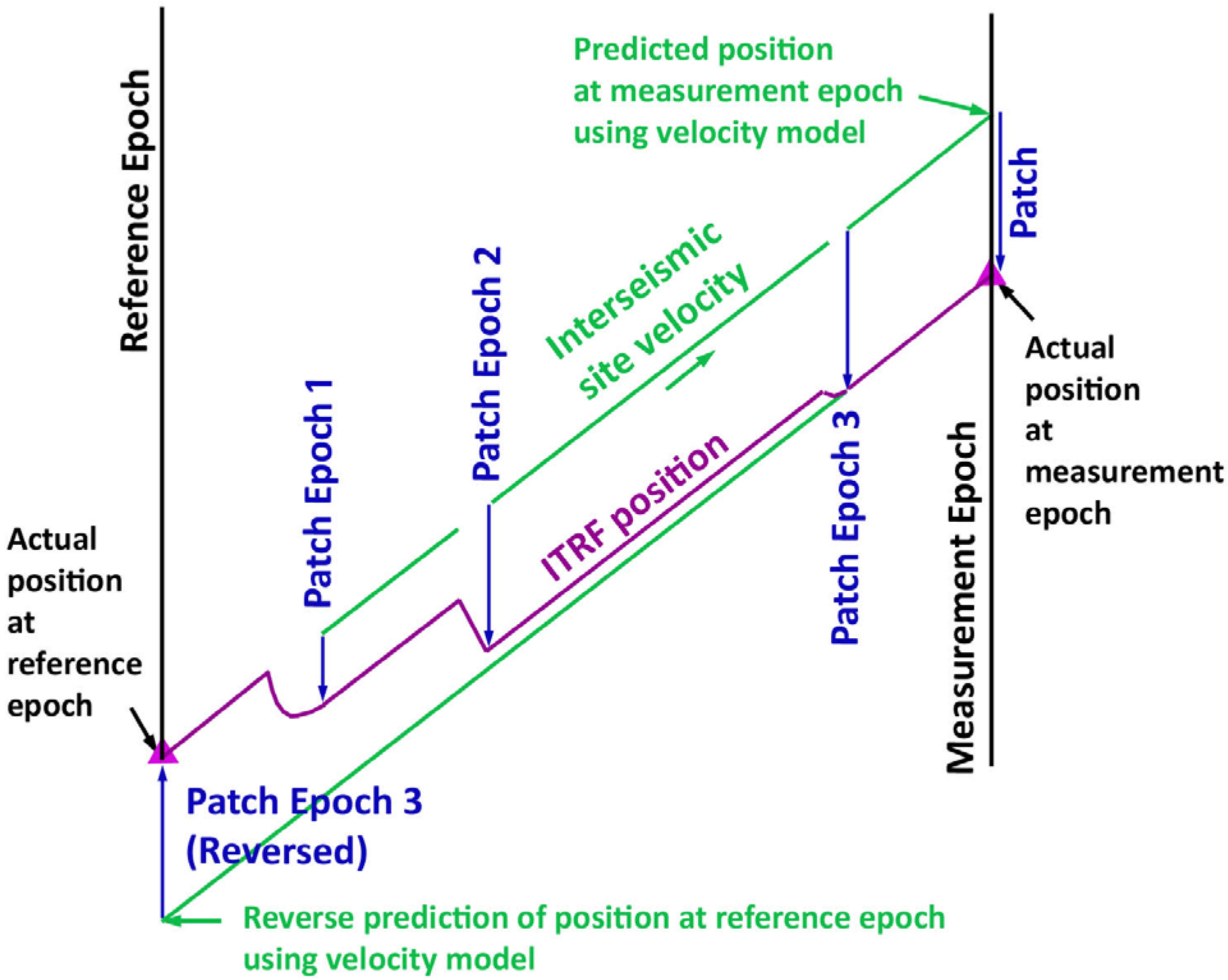
Coseismic offsets and Coordinate Changes



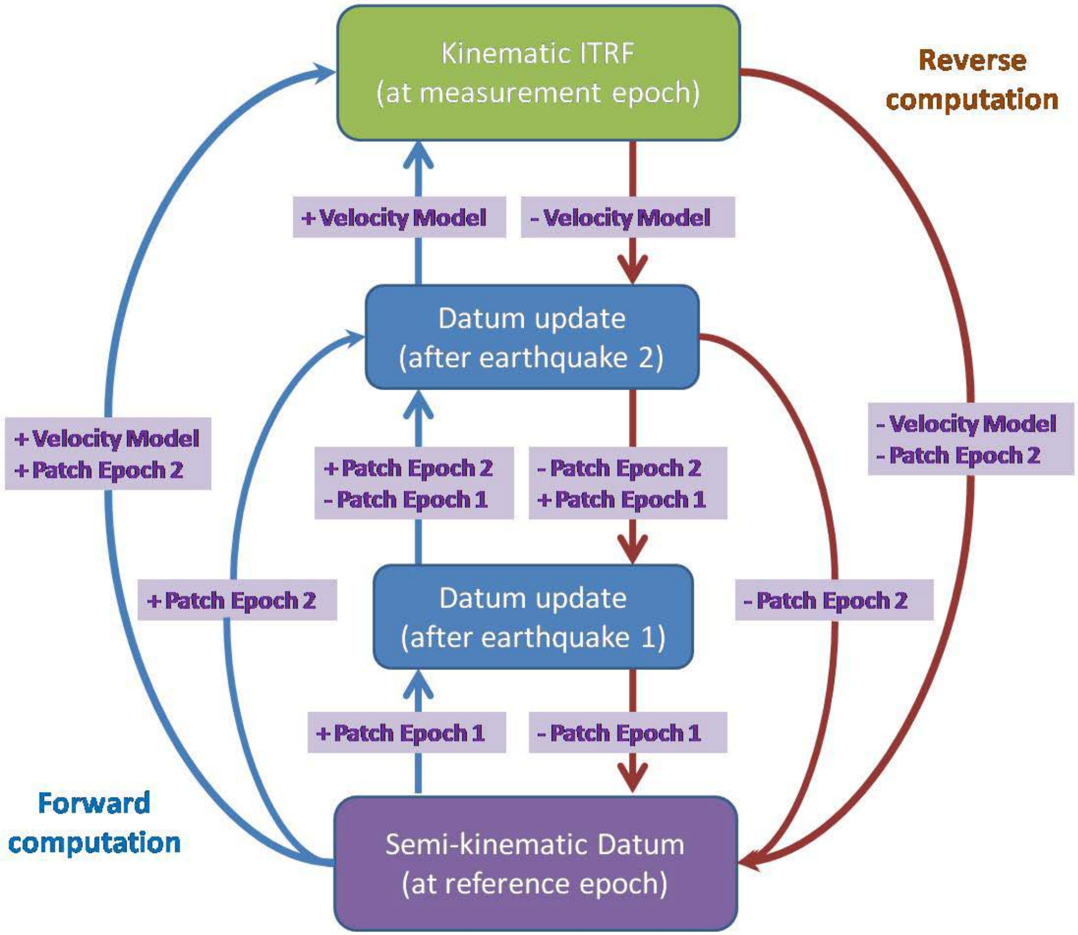


Earthquake induced deformation should result in coordinate changes (seismic patch model) to reflect visible reality – an inconvenient truth.

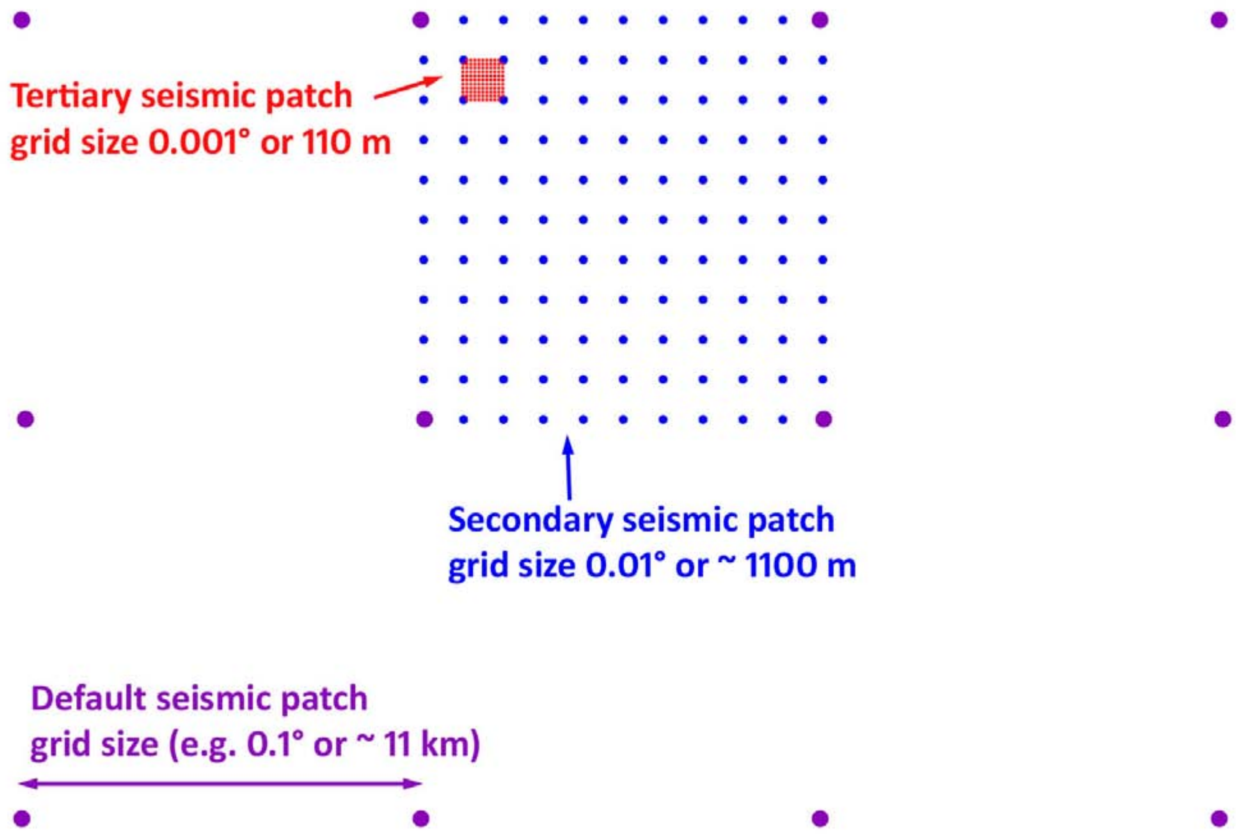
Deformation modelling from time-series analysis



Deformation modelling pathways



Nested data structure for deformation models

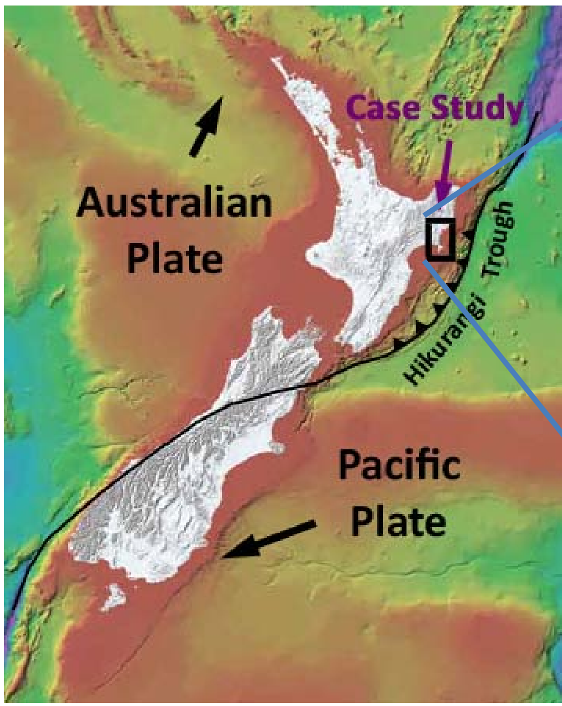


Deformation model in practice

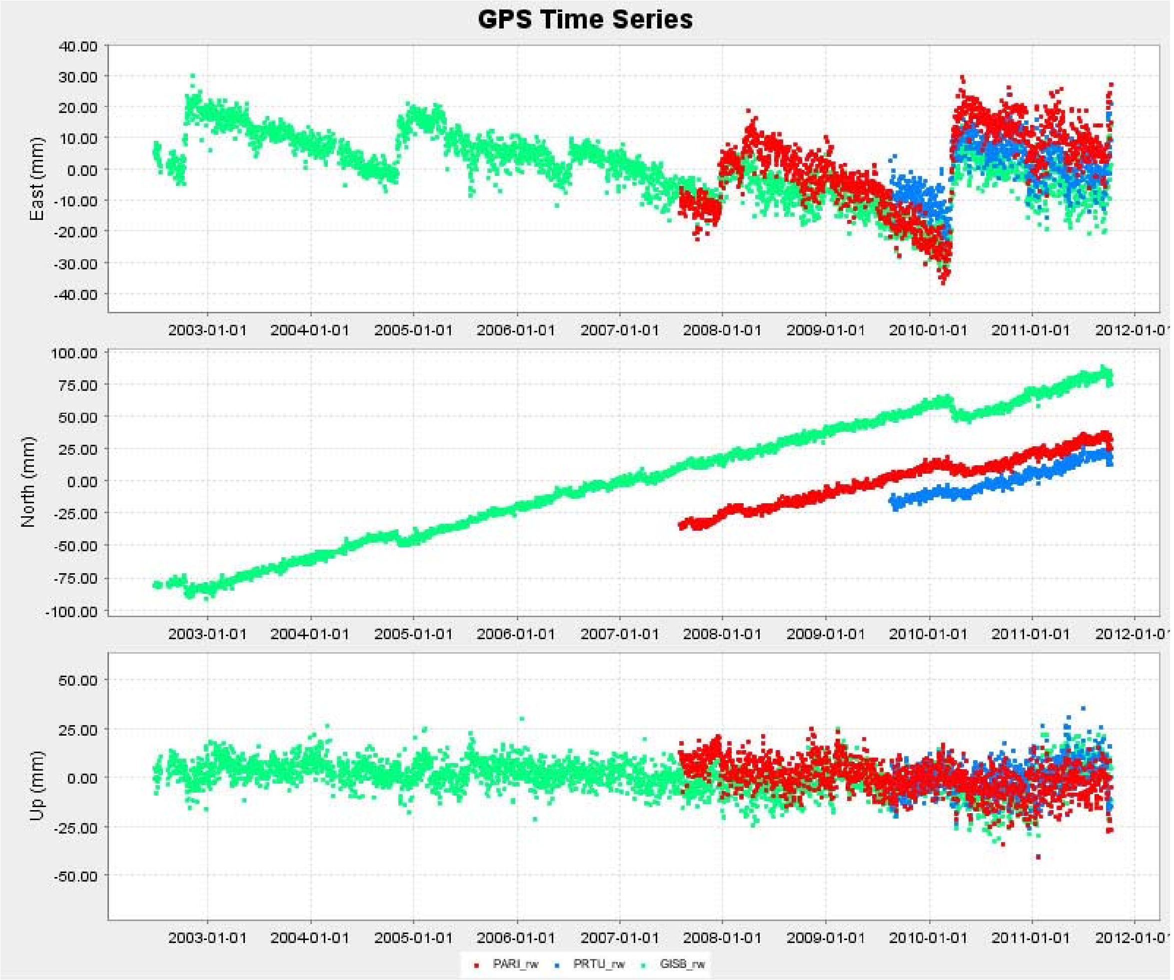
$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{t_0} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{t} + \begin{bmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{bmatrix} \bullet (t_0 - t) - \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix}_{PATCH}$$

t_0	is the reference epoch (in decimal years)
t	is the epoch of measurement (in decimal years)
$(X, Y, Z)t_0$	are the coordinates computed at the reference epoch (metres),
$(X, Y, Z)t$	are the kinematic ITRF coordinates at the measurement epoch (in metres),
$(\dot{X}, \dot{Y}, \dot{Z})$	is the ITRF site velocity interpolated from the interseismic velocity model (m/yr),
$(\Delta X, \Delta Y, \Delta Z)_{PATCH}$	is the accumulated seismic deformation between the reference and measurement epochs interpolated from the most up-to-date seismic patch model (in metres)

New Zealand Case Study



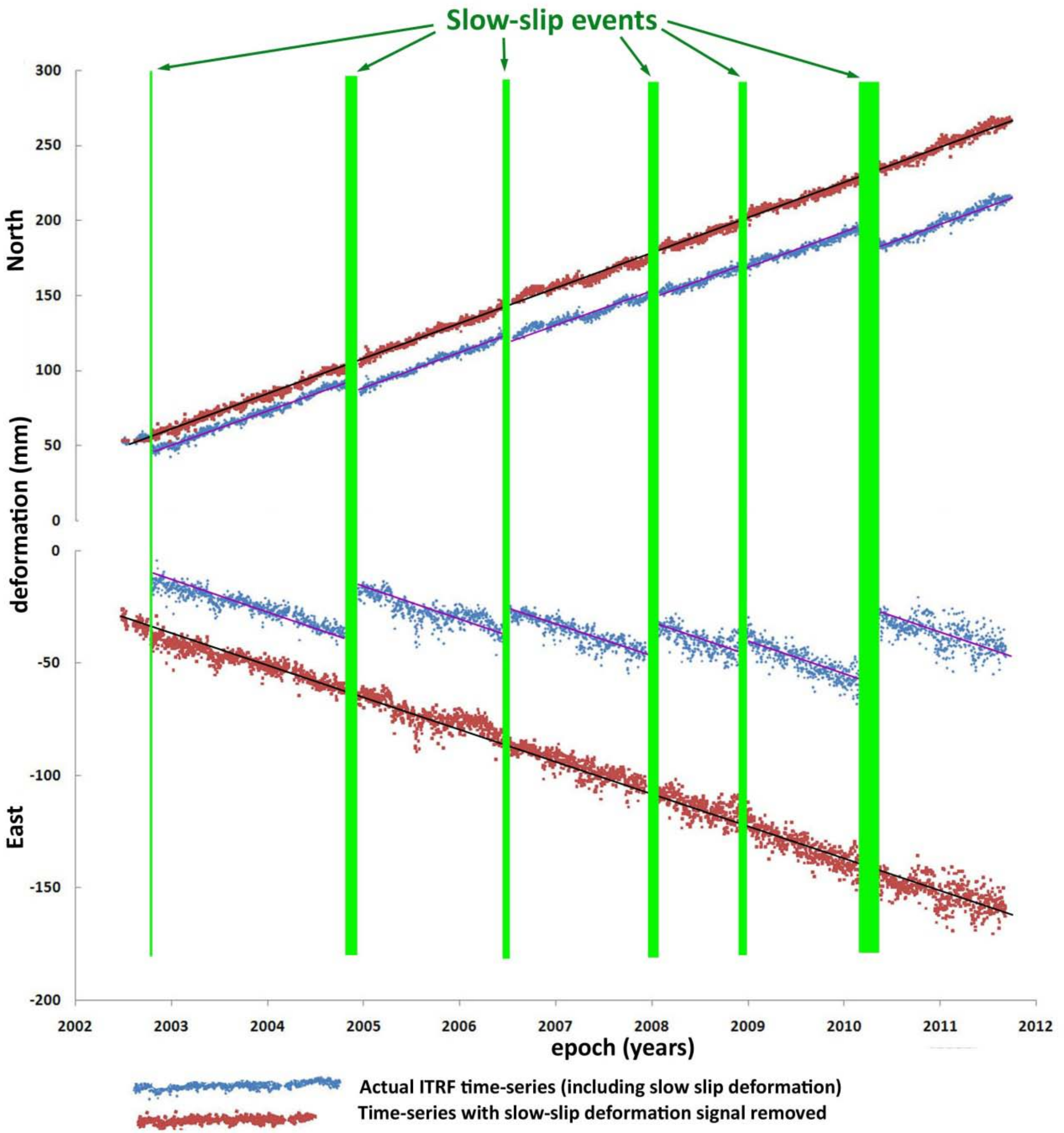
Slow-slip event deformation



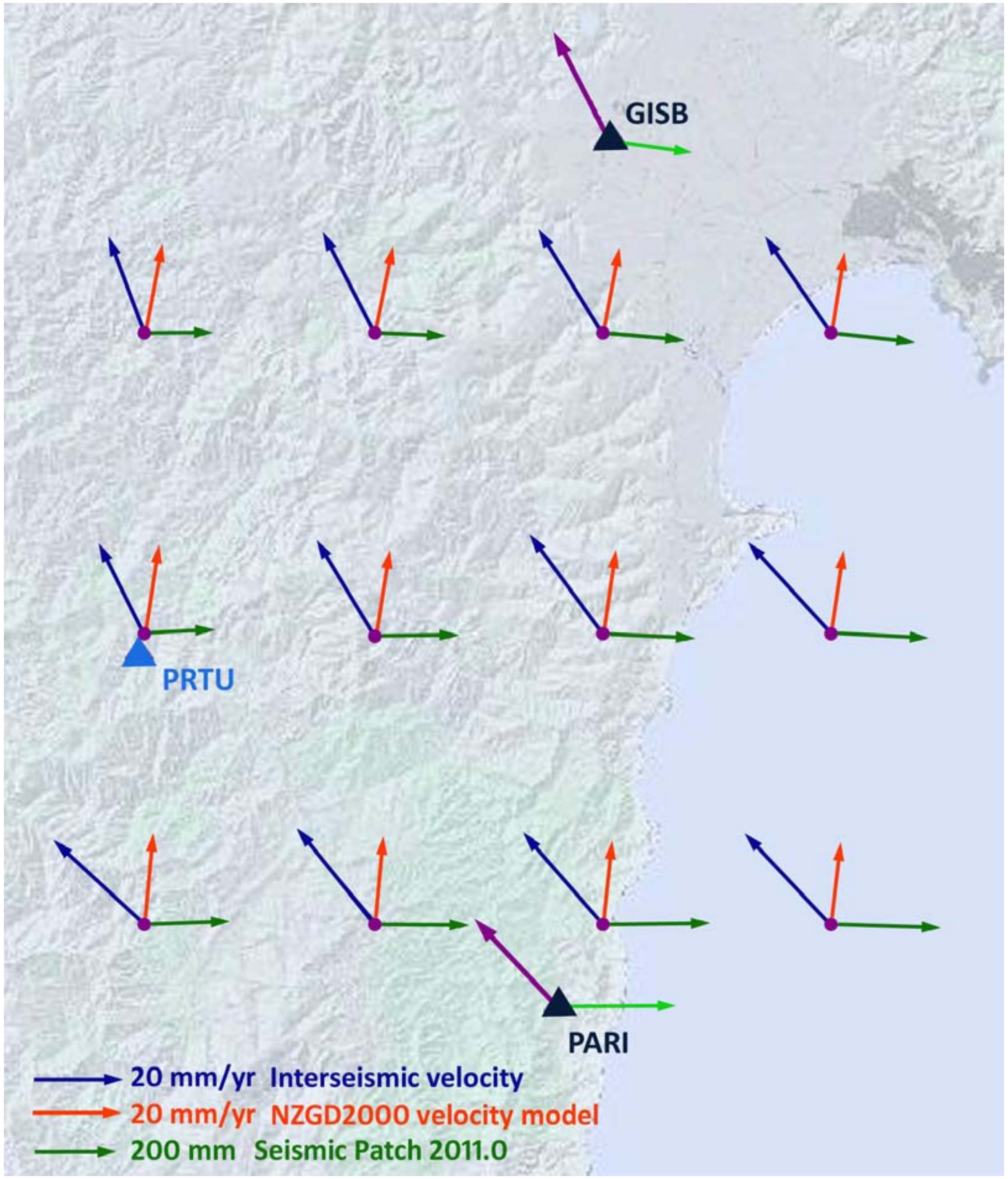
GISB PARI PRTU

Separating seismic and interseismic deformation from time-series

- Seismic patch is a sum of all non-linear (episodic) deformation between reference and measurement epoch



Localised deformation model components



Example

Rover (PRTU)

ITRF2008 Epoch 2011.008	S 38 48' 51.0946"	E 177 41' 52.3646"
The ITRF site velocity from interseismic velocity model :		
	E -0.0108 m/yr	N 0.0217 m/yr
The seismic patch model at epoch 2011.0	ΔE 0.183 m	ΔN 0.008 m
NZGD2000 (estimated from model)	S 38 48' 51.1026"	E 177 41' 52.3620"
NZGD2000 (tabulated)	S 38 48' 51.1021"	E 177 41' 52.3619"
Tabulated – estimated:	**ΔE -0.002 m**	**ΔN 0.014 m**

Conclusions

NRTK should account for reference frame deformation (LU < 15 mm)

NRTK optimally uses latest IGS weekly or daily solution (IGS rapid orbit)

A composite deformation model transforms coordinates between kinematic (dynamic) ITRF/IGS and a static/semi-kinematic datum

1. interseismic velocity model to account for larger and linear plate motion
2. seismic patch model to account for seismic deformation and other distortions

NRTK on rigid plates can use rigid plate rotation model or 14 parameter transformation

NZ Case study shows how concept and application can work in practice

Benefits:

Increased longevity of a working static / semi-kinematic geodetic datum

Complexity of global and local deformations handled at NRTK server or software level

End users do not “see” coordinate changes unless a large earthquake has occurred.