Four Dimensional Deformation Modelling, the link between International, Regional and Local Reference Frames

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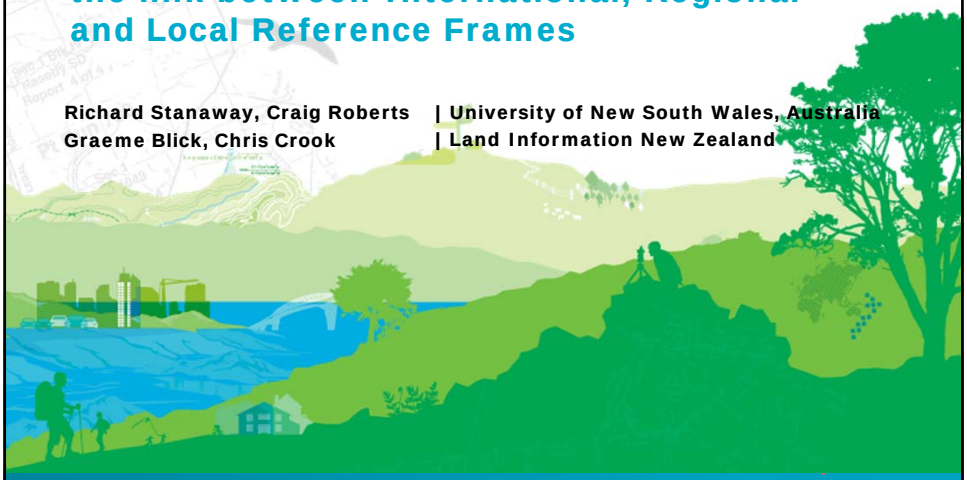


Hierarchy of Reference Frames

Global Reference Frames (e.g. ITRF2008, IGS08, WGS84(G1150))	**Dynamic (kinematic) NNR-Frame**	GNSS data processing & analysis (e.g. PPP, RTK, NRTK, DGPS, Static post-processing) Large-scale deformation analysis, GGOS
Regional Reference Frames (e.g. EUREF, SIRGAS, NAD83, AFREF, APREF)	**Dynamic or semi-dynamic NNR-Frame or plate fixed**	Regional densification of ITRF Connectivity between national datums Overarching frame for national datums / local reference frames
Local Reference Frames (e.g. GDA94, OSGB36, IGM95, NZGD2000)	**Static or semi-dynamic typically plate fixed**	Most spatial applications (e.g. cadastral, engineering, mapping, precision agriculture, mining, LiDar products) terrestrial surveying (e.g. TLS, total-station)

Aim of a 4D Deformation Model

Dynamic (kinematic) NNR-Frame
(e.g. ITRF, WGS84)

14 – parameter transformation or Euler Pole definition

Dynamic Plate-fixed Frame
(e.g. EUREF, NAD83)

7 or 14 – parameter transformation and/or deformation model

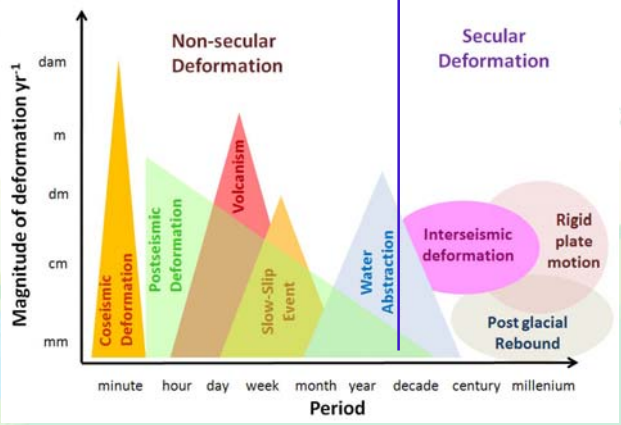
Static or Semi-Dynamic Frame / Datum
(e.g. OSGB36, GDA94, NZGD2000, IGM95)

14 – parameter transformation and/or deformation model

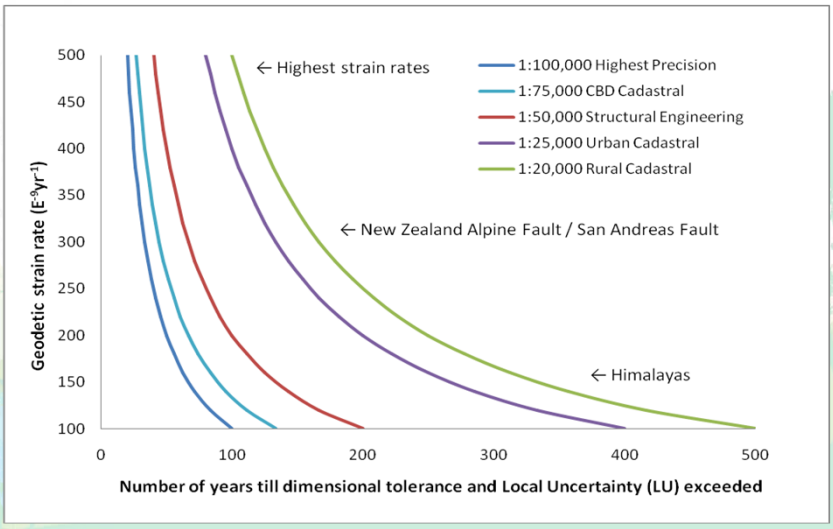
Classification of Deformation

Results in changes in coordinates of local frame
- patch model

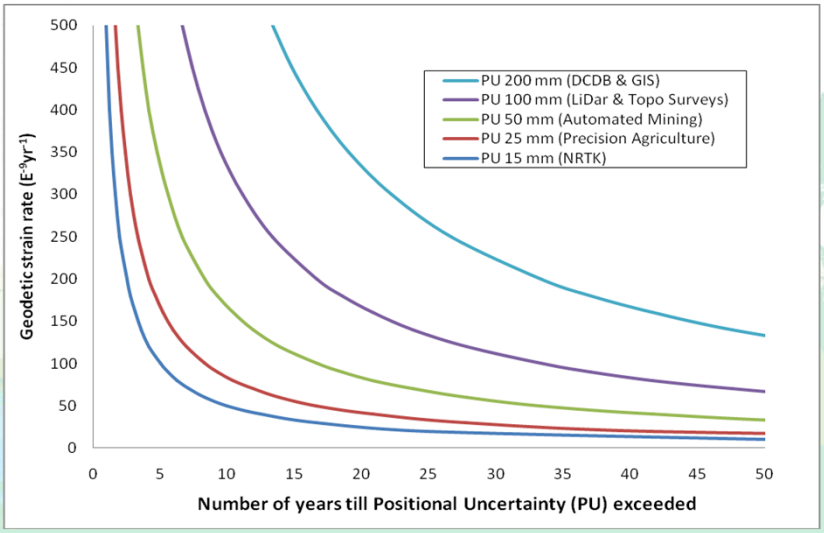
Deformation is "invisible" in local frame
- secular model



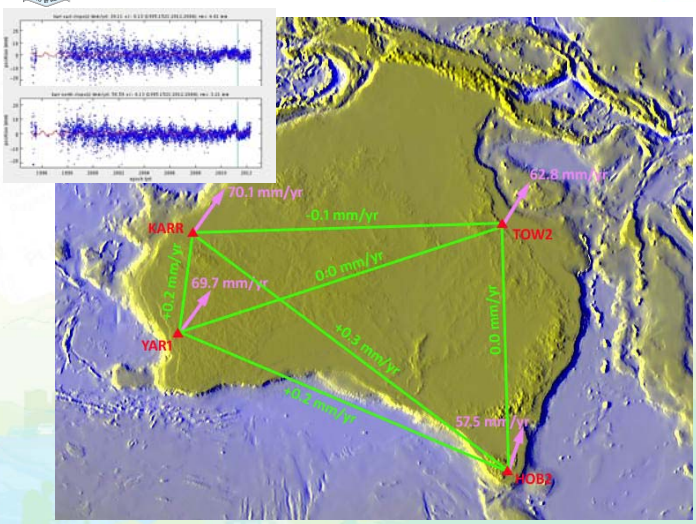
Dimensional Tolerance vs Geodetic Deformation

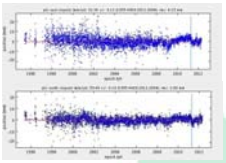


Positional Tolerance vs Geodetic Deformation

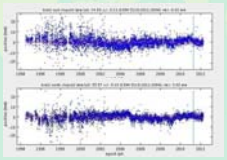


Rigid Plate Deformation



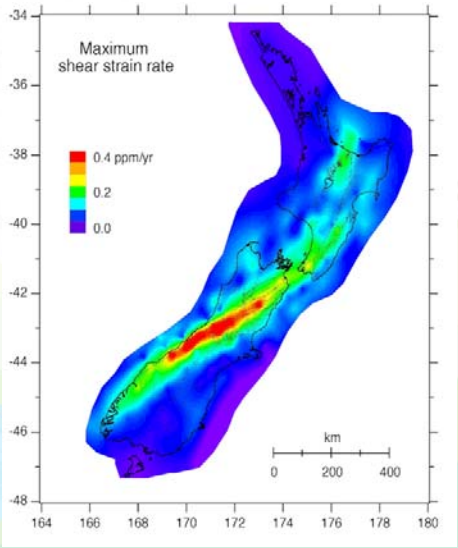


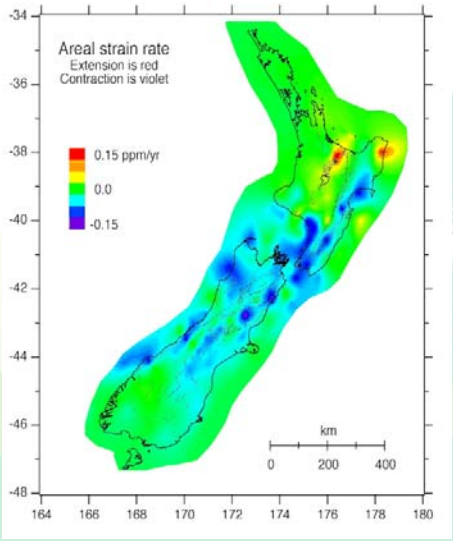
Time-series plots
SCRIPPS, UCSD



purple arrows – tectonic movement, green lines – baseline changes per year

Deformation in Plate Boundary Zones





Developing a Secular Deformation Model

CORS + Campaign GNSS + Static local GNSS surveys

ITRF time-series

Secular component

Non-secular component

Plate rotation parameters
x' y' z

Estimate Euler pole of network
– least squares inversion of site velocities

test inversion – analyse residuals (observed minus modelled velocity)

Residual(s) within tolerance
- rigid network
- no localised deformation

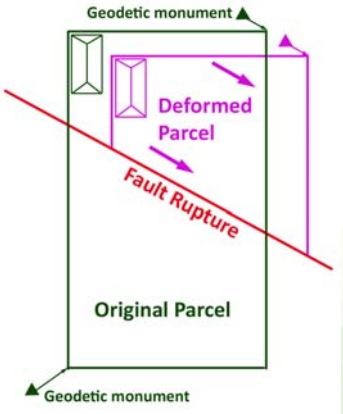
Residual(s) exceed tolerance
- non rigid network, > 1 plates?
- localised deformation?

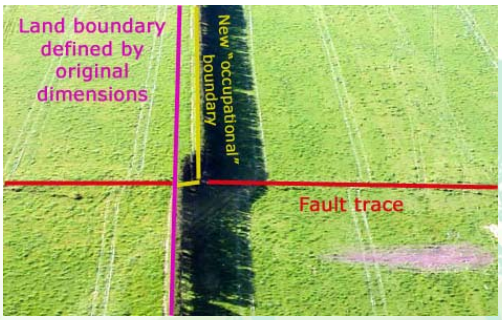
Use Euler pole model
Compute 6 or 14 parameter model

model locked faults – geodetic strain

Gridded – secular deformation model

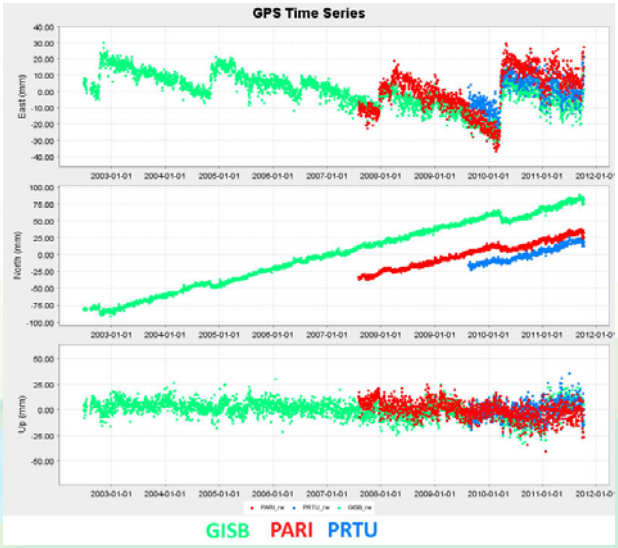
Why episodic events need to be modelled in





Localised deformation should result in coordinate changes to reflect visible reality

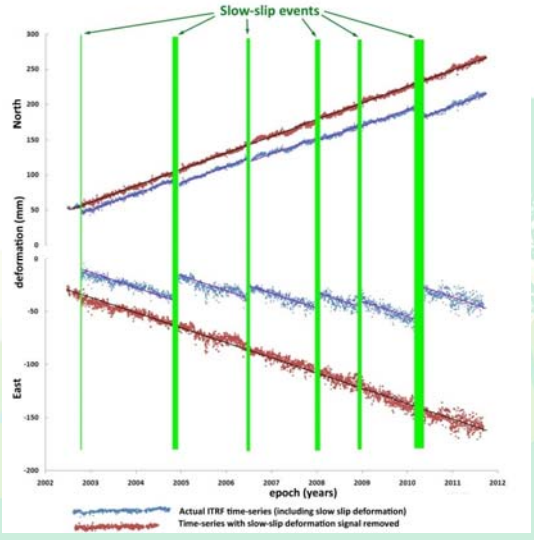
Typical time-series in a deforming zone



Time-series modelling

Separating seismic and secular (interseismic) deformation from time-series

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



Nested model for deformation patch

Model Inputs –

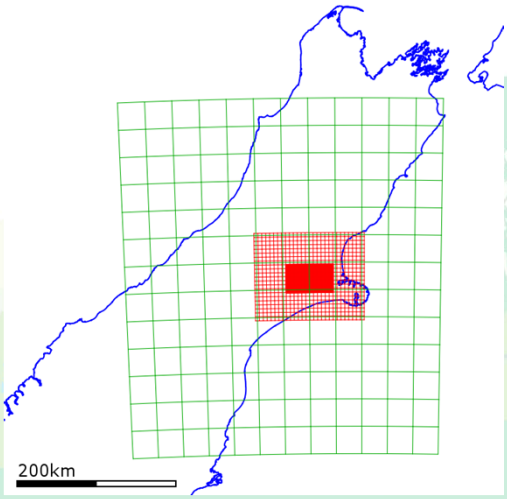
InSAR

LiDar & High-res imagery

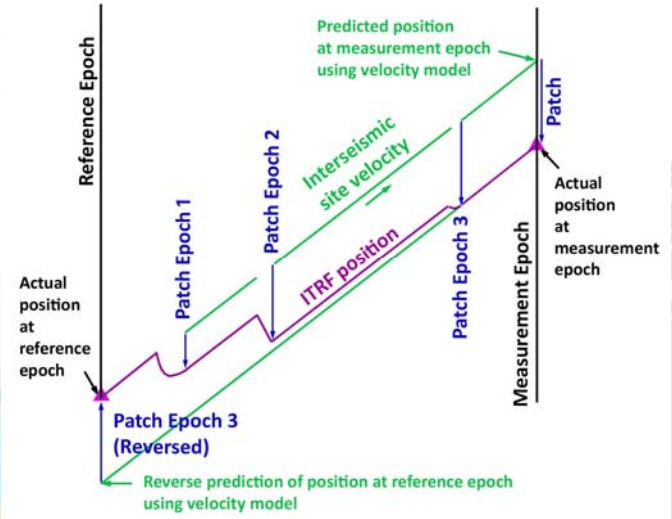
analysis of seismic data

Repeat GNSS obs of dense passive network
(Strong argument for maintaining passive geodetic infrastructure)

Terrestrial surveys



Two modes of deformation - concept

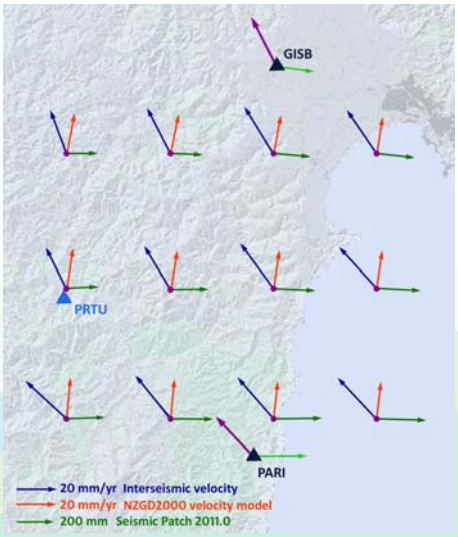


Two modes of deformation in practice

secular model (blue)

patch model (green)

existing model (orange)



Nouva Italia?!