Realisation of a Semi-Kinematic Geodetic Datum using an Absolute Deformation Model (ADM)

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Aim

To provide a linkage between instantaneous (kinematic) ITRF
and a localised fixed epoch realisation of ITRF
(a static or semi-kinematic datum)
to support consistent centimetre precision positioning

Driver (1)

User level precise positioning at mm/cm level

Natural Resources Canada > Earth Sciences Sector > Priorities > Canadian Spatial Reference System

Canadian Spatial Reference System

CSRS-PPP

CSRS-PPP is an on-line application for GPS data post-processing that allows GPS u submit observation data over the Internet and recover, using precise GPS Orbit and clock information, enhanced positioning precisions in the Canadian Spatial Reference System (CSRS) and the International Terrestrial Reference Frame (ITRF).

Select RINEX Observation File

(Name: use only Western Roman alphanumerics, including hyphen and underscore)
(Compression: none or zip (.zip), gzip (.gz) or UNIX Compress (.Z))
(Format: RINEX or Compact RINEX (Hatanaka))

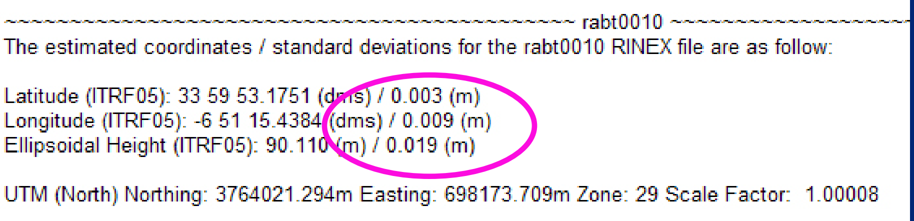
Select Mode of Processing: Static

Select Reference System: ITRF (Epoch of GPS data)

Enter/Change E-Mail to which results will be sent: richard.stanaway@quickclose.com.au

File Upload/Processing

Date Modified: 2009-02-25



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~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ rabt0010 ~~~~~~~~~~~~~~~~~~~~
The estimated coordinates / standard deviations for the rabt0010 RINEX file are as follow:

Latitude (ITRF05): 33 59 53.1751 (dms) / 0.003 (m)
Longitude (ITRF05): -6 51 15.4384 (dms) / 0.009 (m)
Ellipsoidal Height (ITRF05): 90.110 (m) / 0.019 (m)

UTM (North) Northing: 3764021.294m Easting: 698173.709m Zone: 29 Scale Factor:  1.00008
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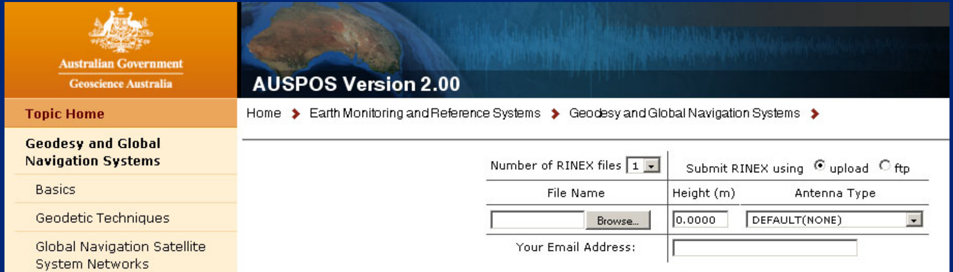
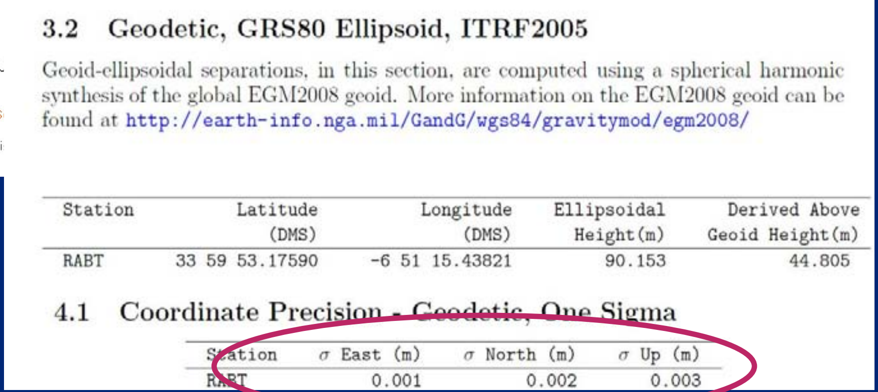


Number of RINEX files 1 | Submit RINEX using ● upload ○ ftp

File Name	Height (m)	Antenna Type
	0.0000	DEFAULT(NONE)

Your Email Address:



3.2 Geodetic, GRS80 Ellipsoid, ITRF2005

Geoid-ellipsoidal separations, in this section, are computed using a spherical harmonic synthesis of the global EGM2008 geoid. More information on the EGM2008 geoid can be found at http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm2008/

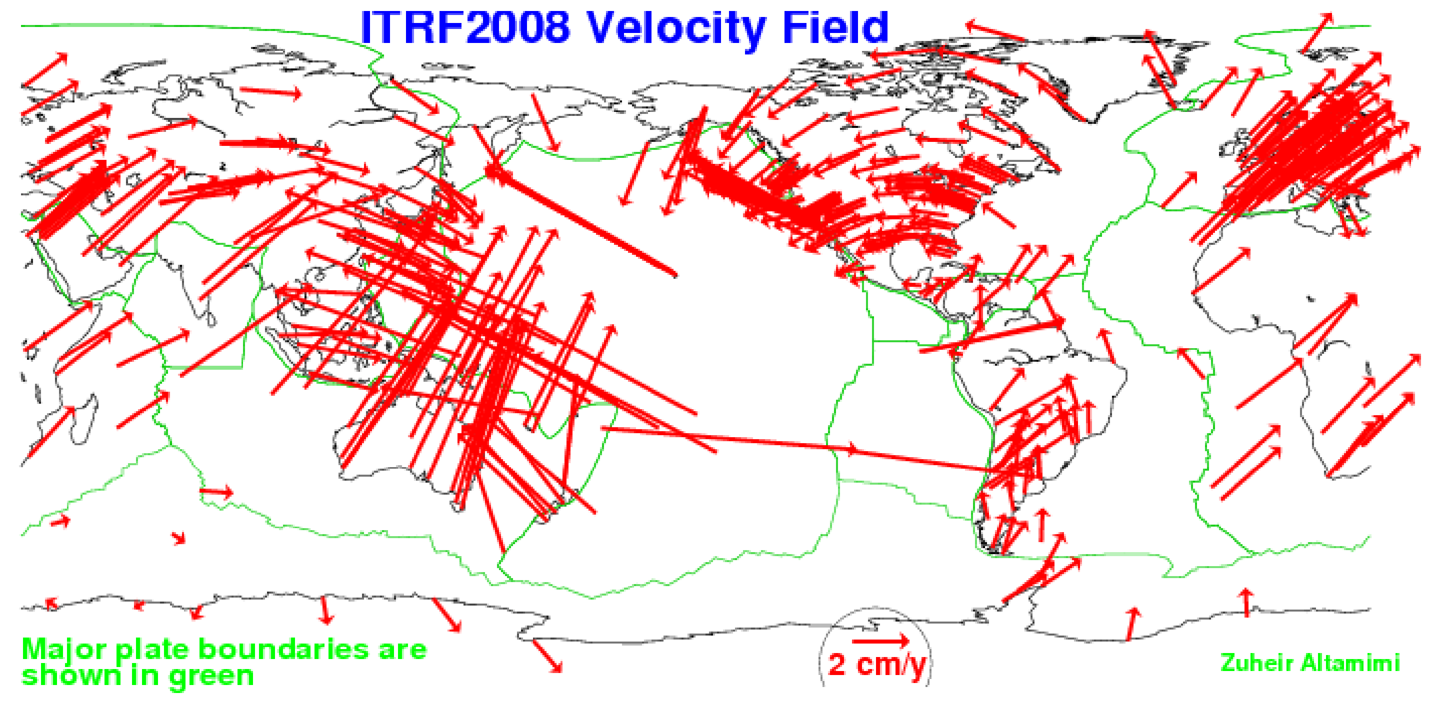
Station	Latitude (DMS)	Longitude (DMS)	Ellipsoidal Height(m)	Derived Above Geoid Height(m)
RABT	33 59 53.17590	-6 51 15.43821	90.153	44.805

4.1 Coordinate Precision - Geodetic, One Sigma

Station	σ East (m)	σ North (m)	σ Up (m)
RABT	0.001	0.002	0.003

OmniSTAR
A DIVISION OF TRIMBLE

Driver (2) ITRF Site velocities – tectonic deformation



Zuheir
Altamimi
IERS

Interseismic and rigid plate deformation up to 90 mm/yr

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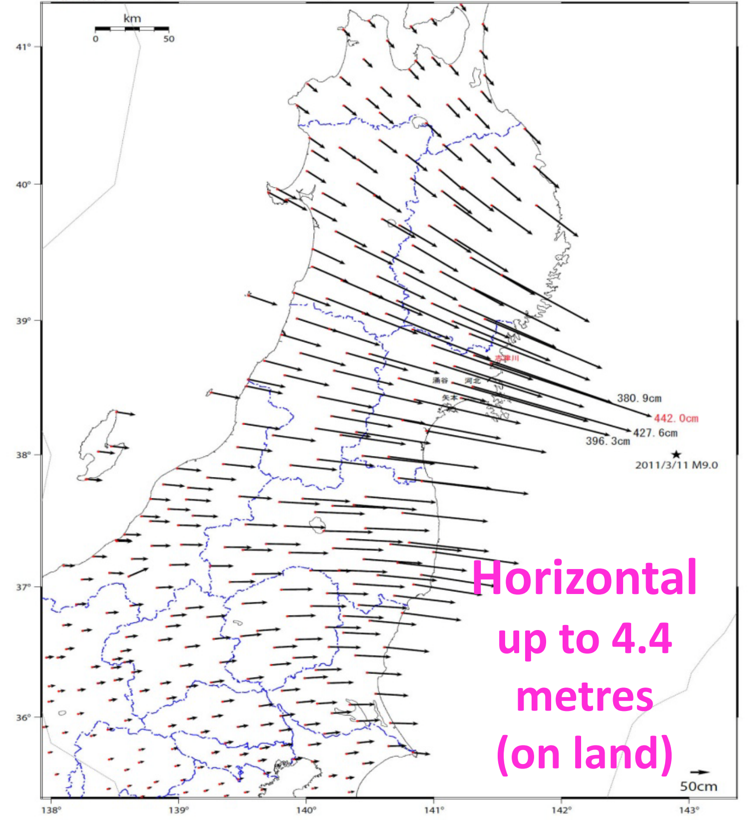
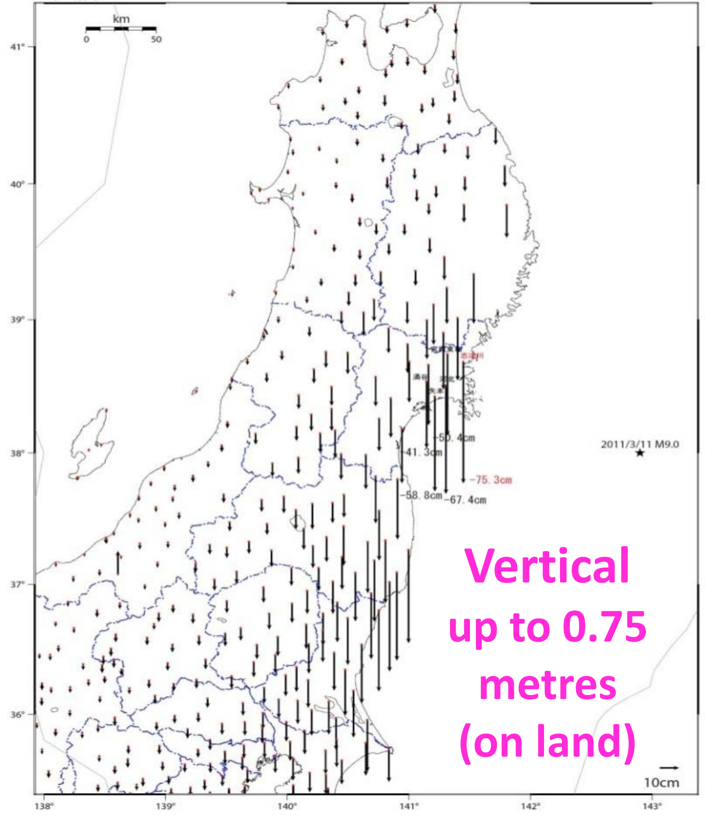
(3) Regional Coseismic Deformation

M9.0 Tōhuku Earthquake, Japan 11th March 2011



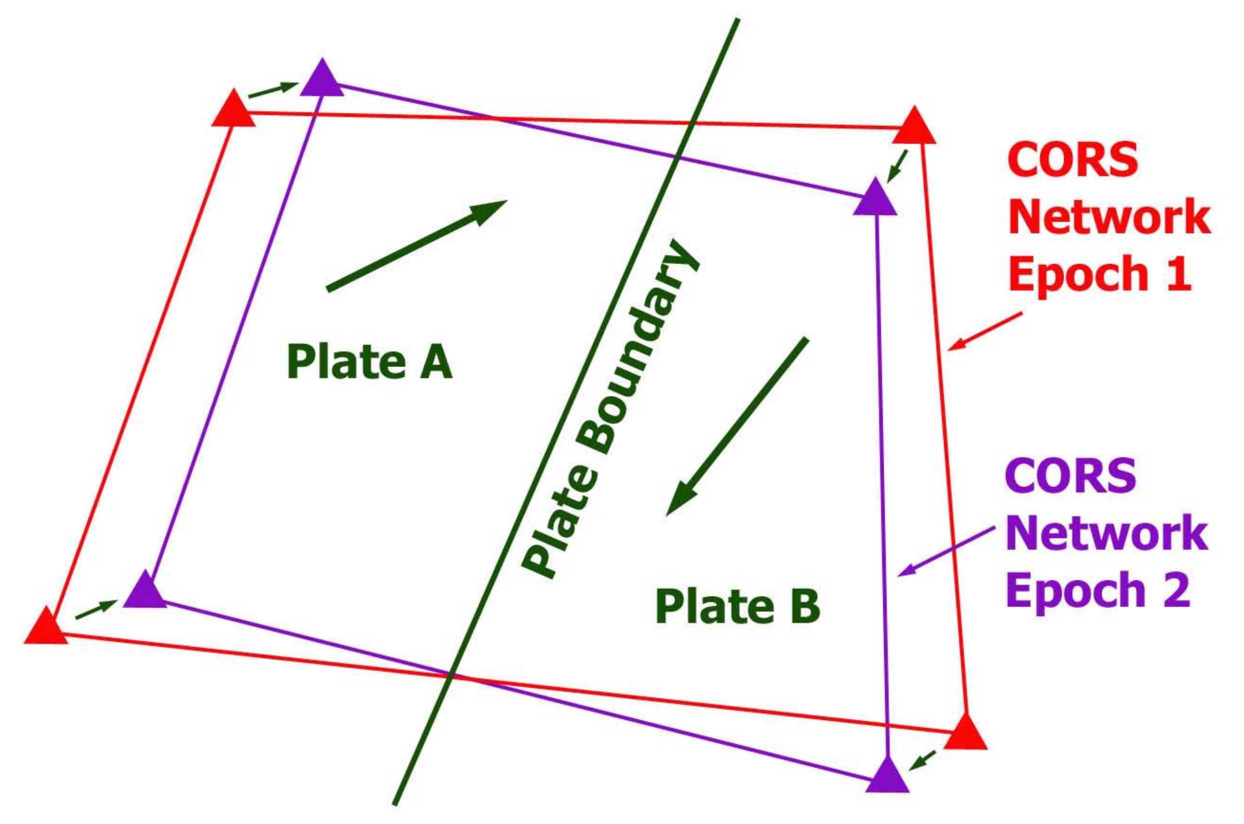
Horizontal up to 4.4 metres (on land)



Vertical up to 0.75 metres (on land)

images: Geospatial Information Authority of Japan *www.gsi.go.jp/chibankansi/chikakukansi_tohoku.html*

Effect of tectonic deformation on a geodetic/CORS network



Example:
"Fixing" CORS coordinates
in a deforming zone will rapidly degrade performance and precision of NTRK

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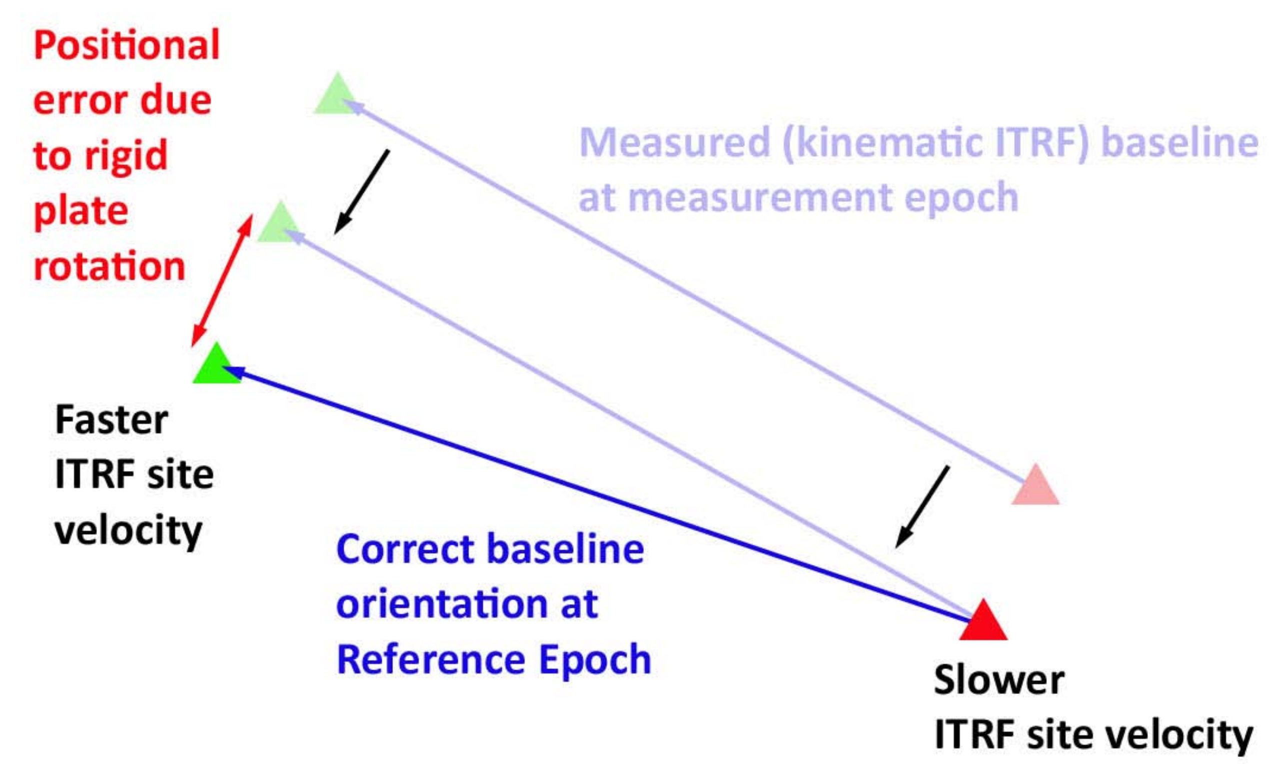
Effect of Rigid Plate Rotation on long GNSS baselines



Positional error due to rigid plate rotation

Measured (kinematic ITRF) baseline at measurement epoch

Faster ITRF site velocity

Correct baseline orientation at Reference Epoch

Slower ITRF site velocity

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Kinematic or Semi-kinematic??

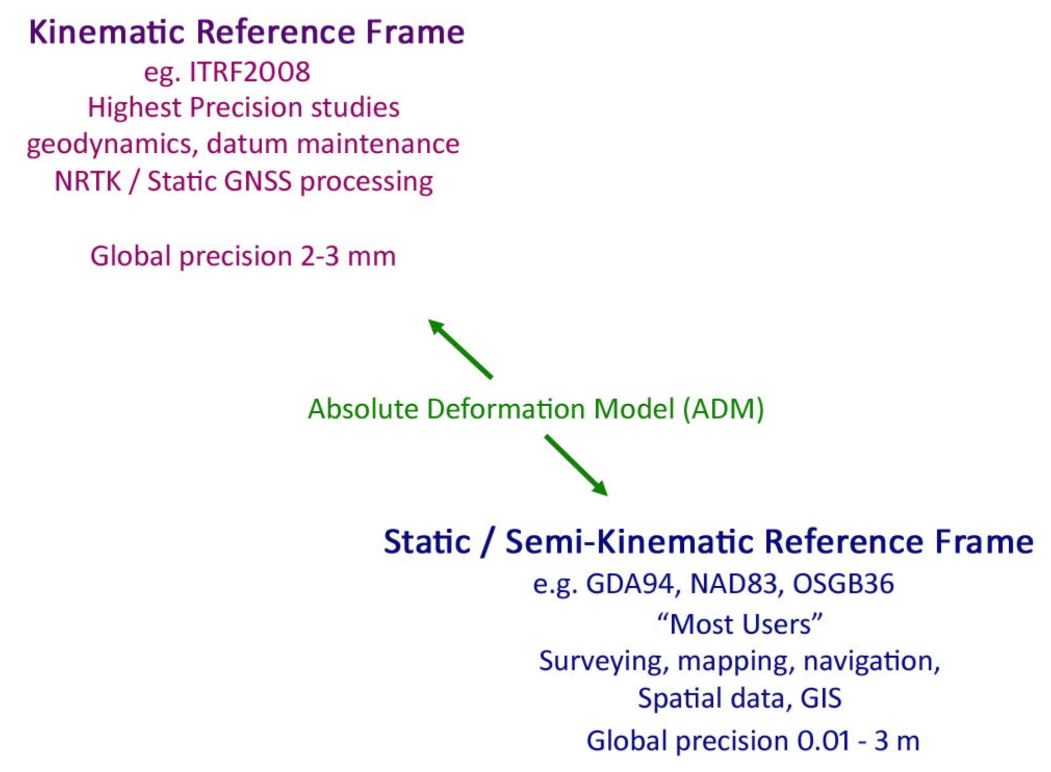
A kinematic datum (e.g. ITRF) overcomes many of the limitations of unmodelled deformation within a “static” network

BUT

For most prosaic spatial applications (e.g. cadastral surveys, GIS, terrestrial/airborne laser scanning, precision agriculture, automated mining, automated navigation ....) constantly changing coordinates are not practicable.
The legal definition of a coordinate also becomes complex.

For example: How are Terabyte/Petabyte sized 3D point clouds acquired at different epochs of ITRF integrated or analysed??

Hierarchy and linkage of reference frames – Global to Local



Kinematic Reference Frame

eg. ITRF2008

Highest Precision studies

geodynamics, datum maintenance

NRTK / Static GNSS processing

Global precision 2-3 mm

Absolute Deformation Model (ADM)

Static / Semi-Kinematic Reference Frame

e.g. GDA94, NAD83, OSGB36

“Most Users”

Surveying, mapping, navigation,

Spatial data, GIS

Global precision 0.01 - 3 m

GNSS data processing best achieved using ITRF or IGS08 coordinates at the epoch of observation (kinematic ITRF).

This overcomes the adverse effects of unmodelled network deformation and rigid rotation.

ADM then used to recover reference epoch

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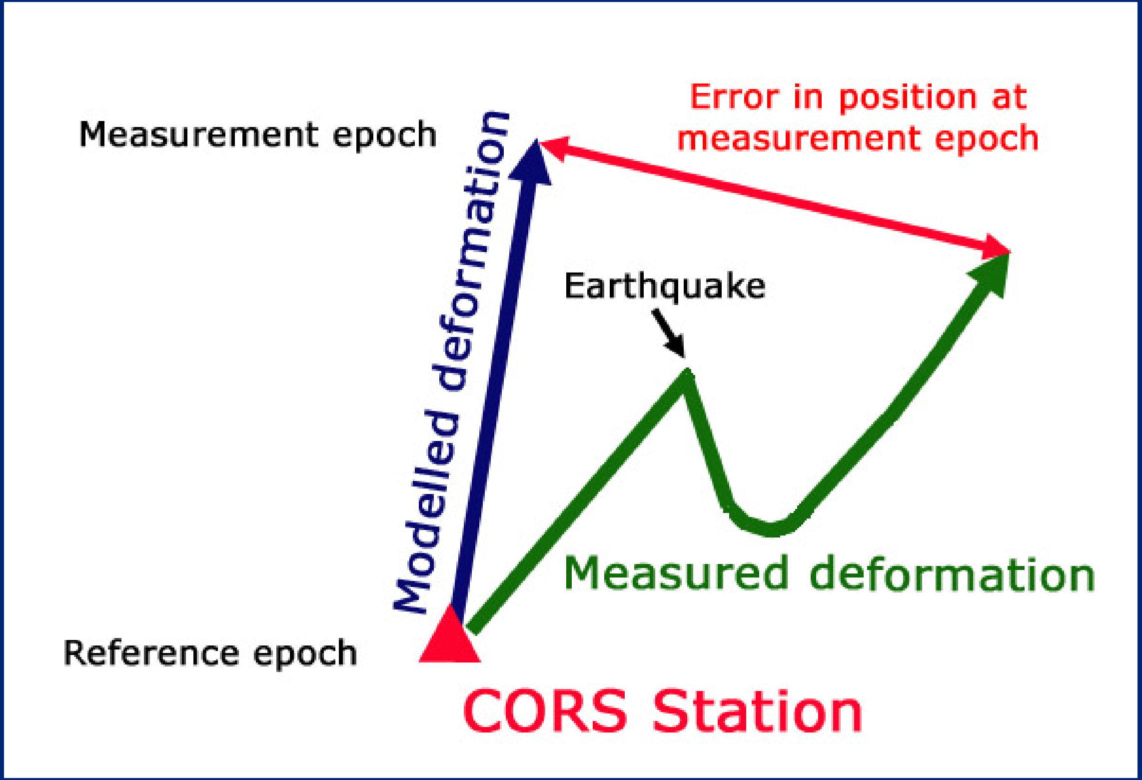
Requirement for a survey accurate deformation model



Effect of imprecise modelling assumptions on measurement precision

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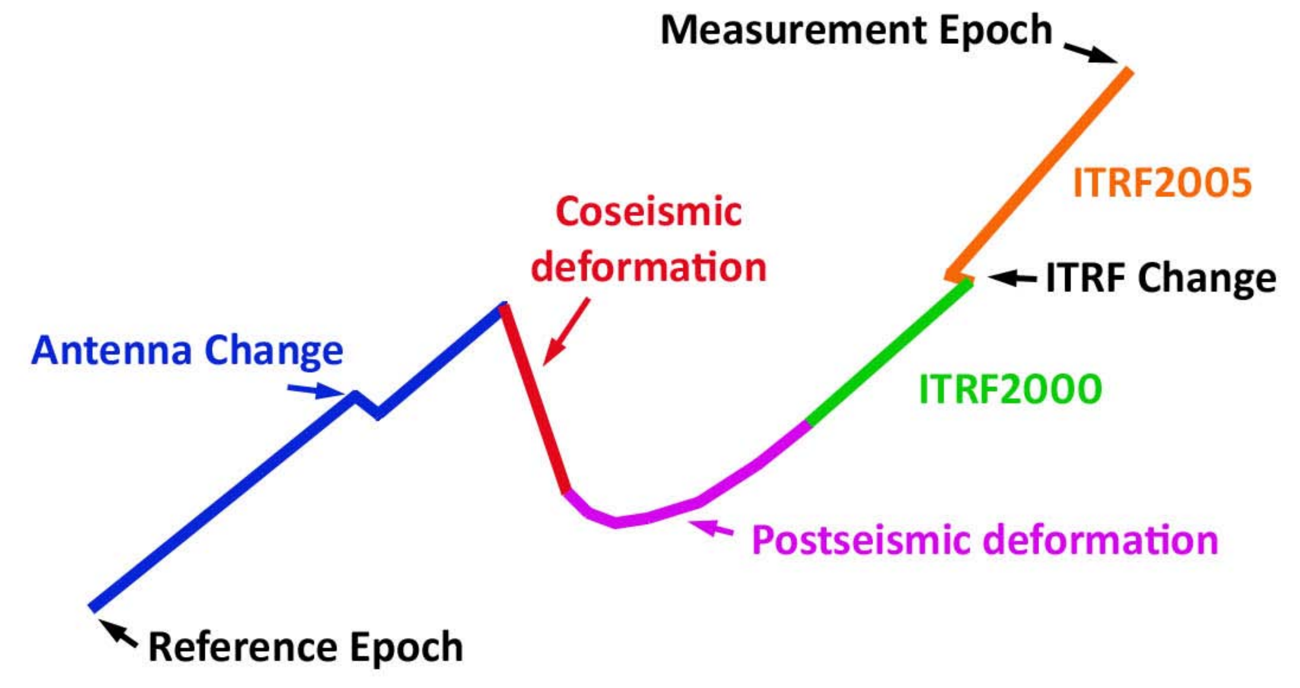
Absolute Deformation Model (ADM) Concept



Typical positional time series in a complex deformation setting

An ADM should be able to recover reference epoch coordinates from any measurement epoch within a specified precision or tolerance

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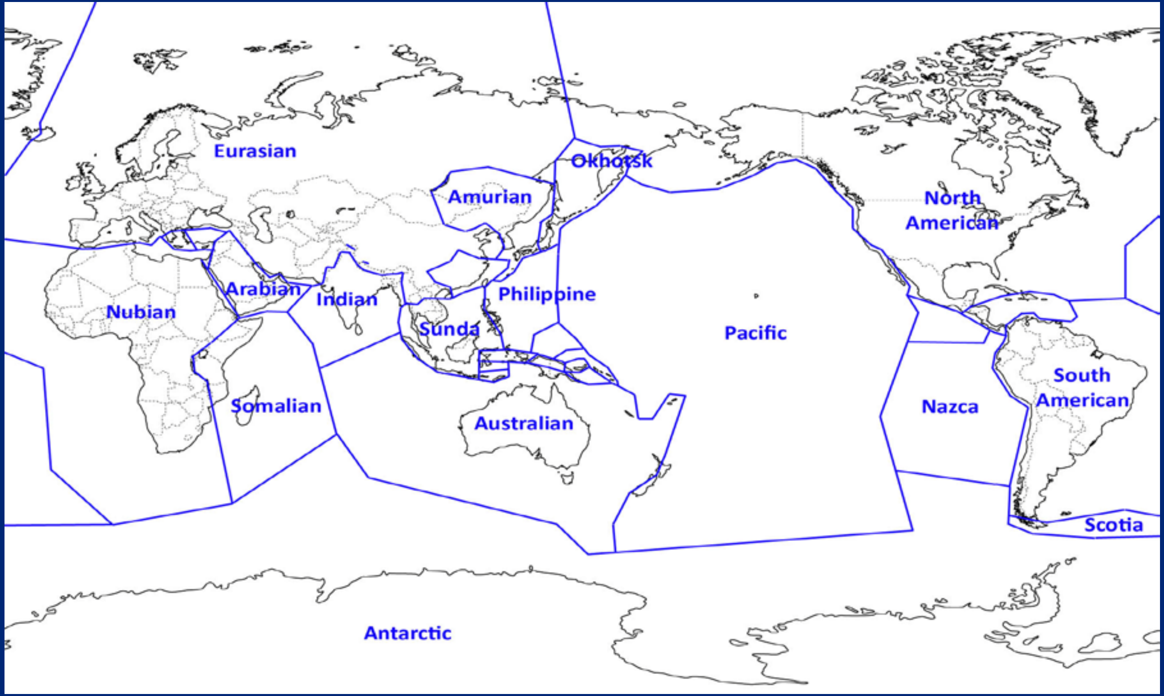
Primitive ADM Structure: (1) Rigid Plate polygon model



Three parameter transformation for each plate. Fails in boundary zones where deformation near locked faults is not modelled (~ 3% Earth surface)

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Kinematic to Static transformation on a rigid plate

$$\begin{bmatrix}X_0\\Y_0\\Z_0\end{bmatrix} = \begin{bmatrix}T_X\\T_Y\\T_Z\end{bmatrix} + S\cdot\left[\begin{bmatrix}X_t\\Y_t\\Z_t\end{bmatrix} + \begin{bmatrix}\boxed{\Omega_Y} Z_t - \Omega_Z Y_t\\ \boxed{\Omega_Z} X_t - \Omega_X Z_t\\ \boxed{\Omega_X} Y_t - \Omega_Y X_t\end{bmatrix}\cdot(t_0 - t)\cdot 1\text{E-6}\right]$$

Local frame translation & scale (only if required)

Plate rotation parameters

reference epoch

measurement epoch

"Static" coordinates at reference epoch

"Measured" e.g. ITRF coordinates

$$X_0 = X_t + (\Omega_Y Z_t - \Omega_Z Y_t).(t_0 - t)\cdot 1\text{E-6}$$
$$Y_0 = Y_t + (\Omega_Z X_t - \Omega_X Z_t).(t_0 - t)\cdot 1\text{E-6}$$
$$Z_0 = Z_t + (\Omega_X Y_t - \Omega_Y X_t).(t_0 - t)\cdot 1\text{E-6}$$

Simplified
3-parameter equations
Kinematic ITRF to
Static ITRF
(no scale or translation parameters)

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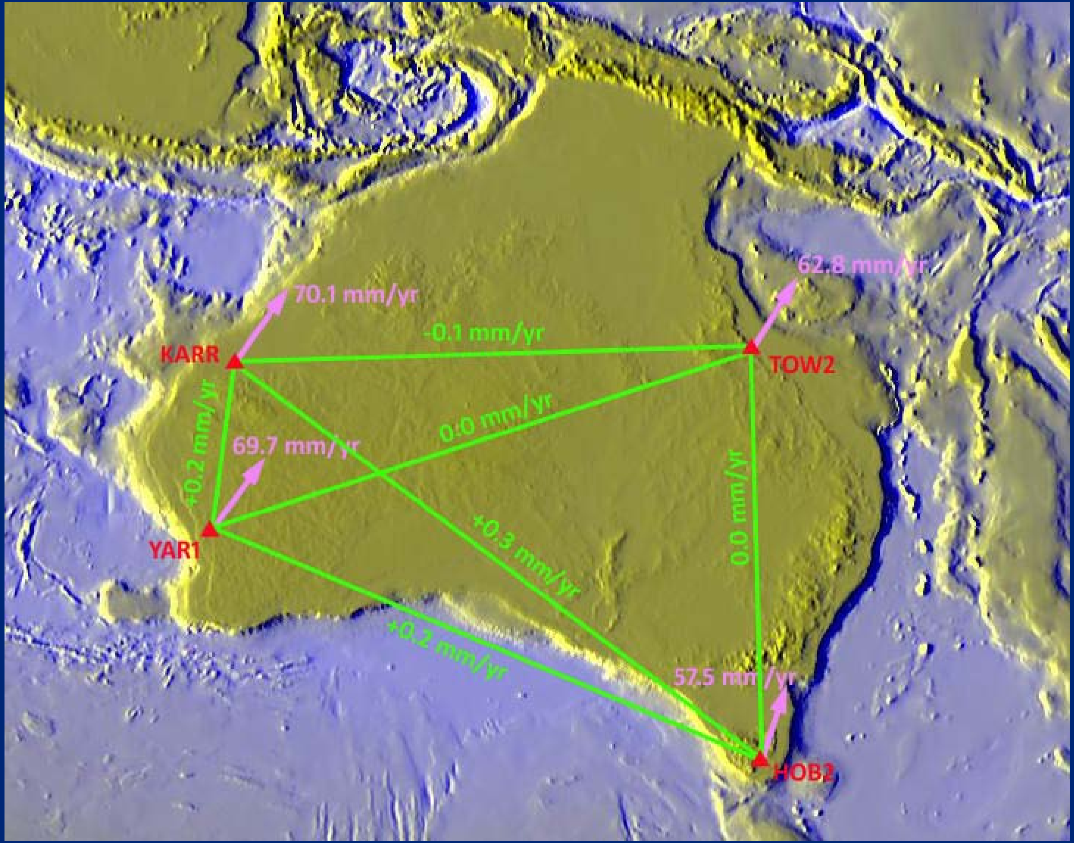
Characteristics of a datum fixed to a rigid tectonic plate



Benefits:

Internal deformation typically < 1 mm/yr (3 par. model useful for 10-30 years)

Limitations

Divergence between static coordinates and kinematic ITRF up to 80 mm/yr.

Effect of far-field deformation from very large earthquakes

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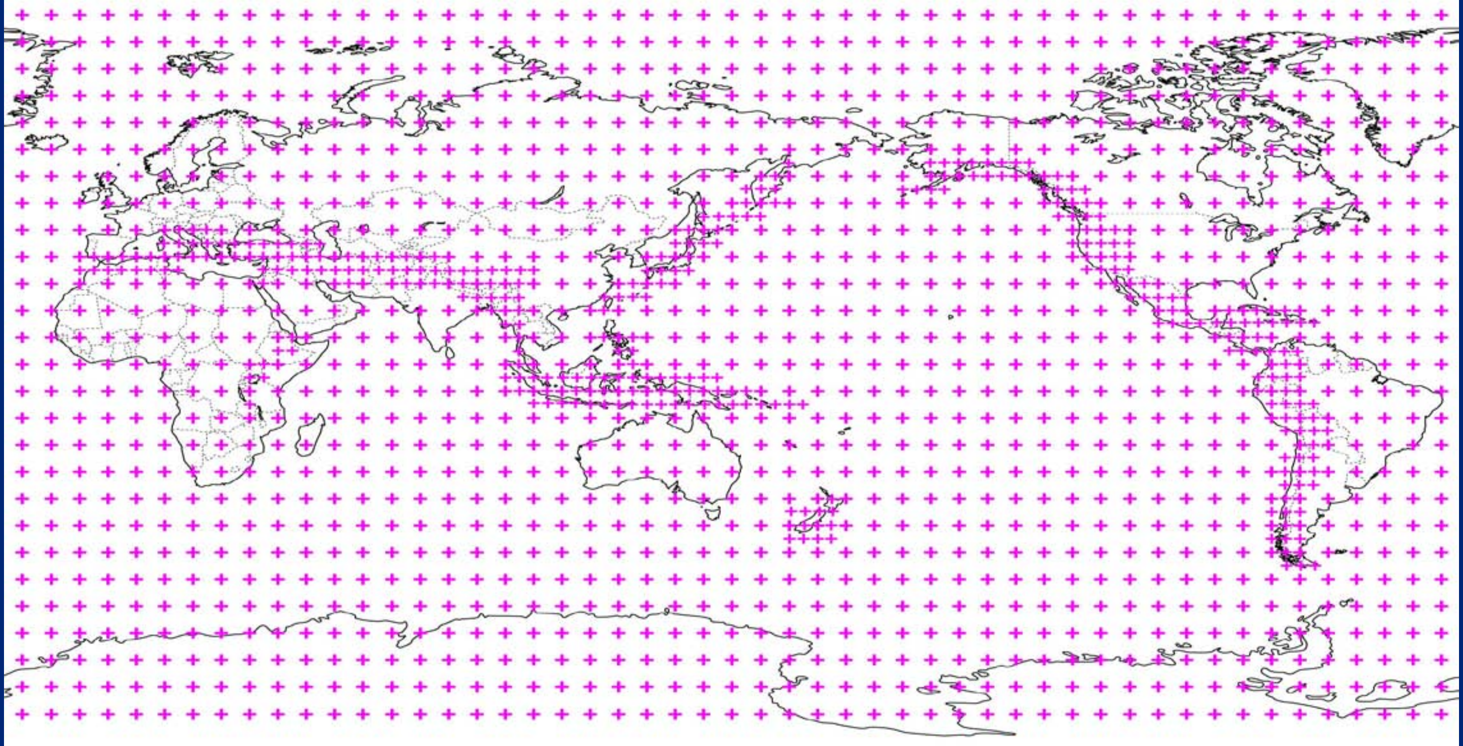
Primitive ADM Structure: (2) Irregular global grid of site velocities



Increased density of grid size near plate boundaries
Interpolation fails in close proximity of locked faults

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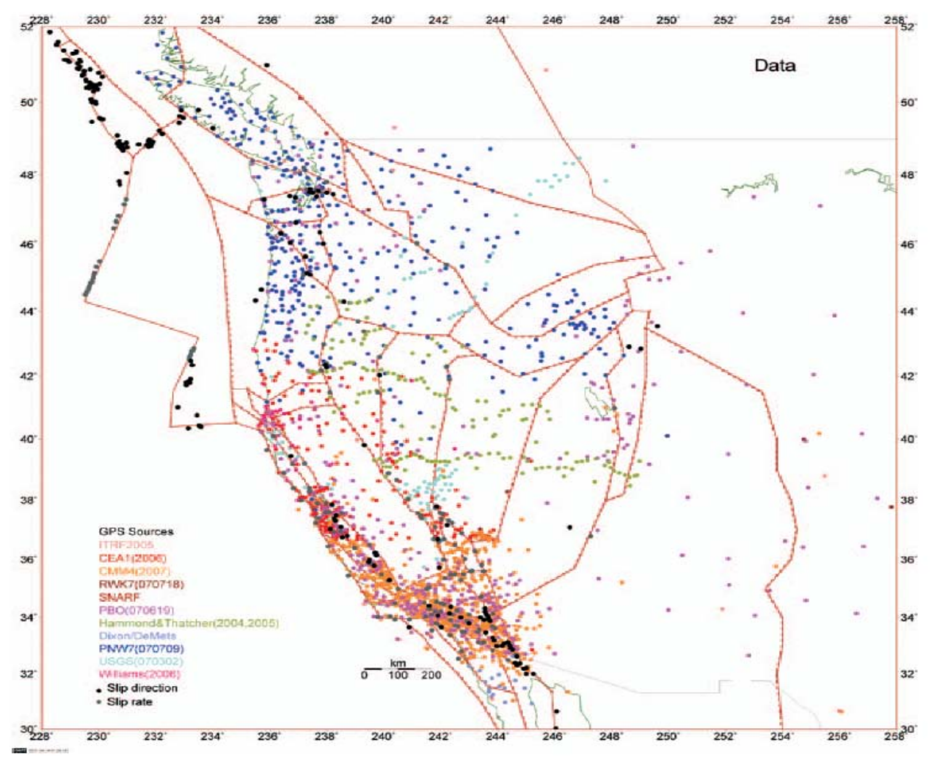
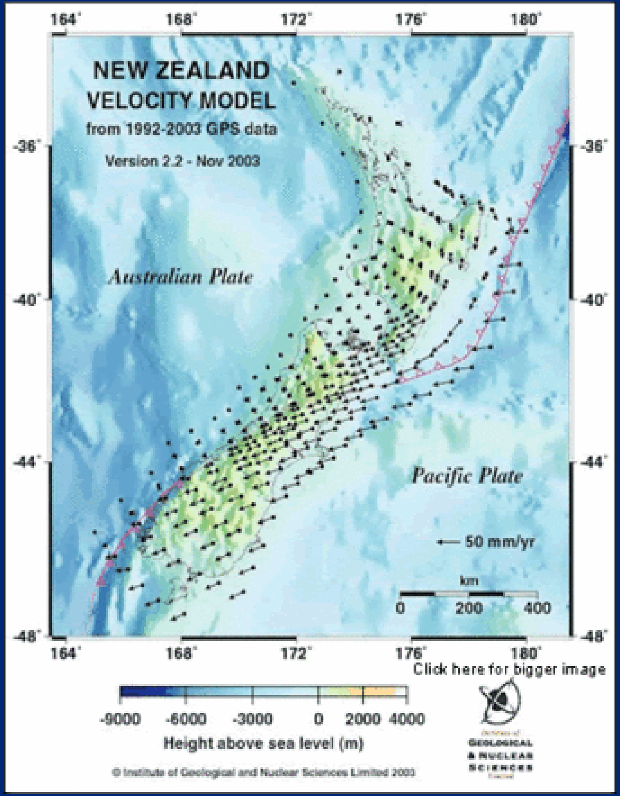
ADM Structure: (3) Polygon and Fault locking model



e.g. US HTDP (Snay, Pearson, McCaffrey)

Relative Deformation Model e.g. New Zealand



Modelled velocities with respect to fixed Australian Plate

Requires localised transformation from ITRF2008 to ITRF96 at epoch 2000.0 (NZGD2000 reference epoch)

Modelled velocity not exactly aligned with recent CORS ITRF timeseries

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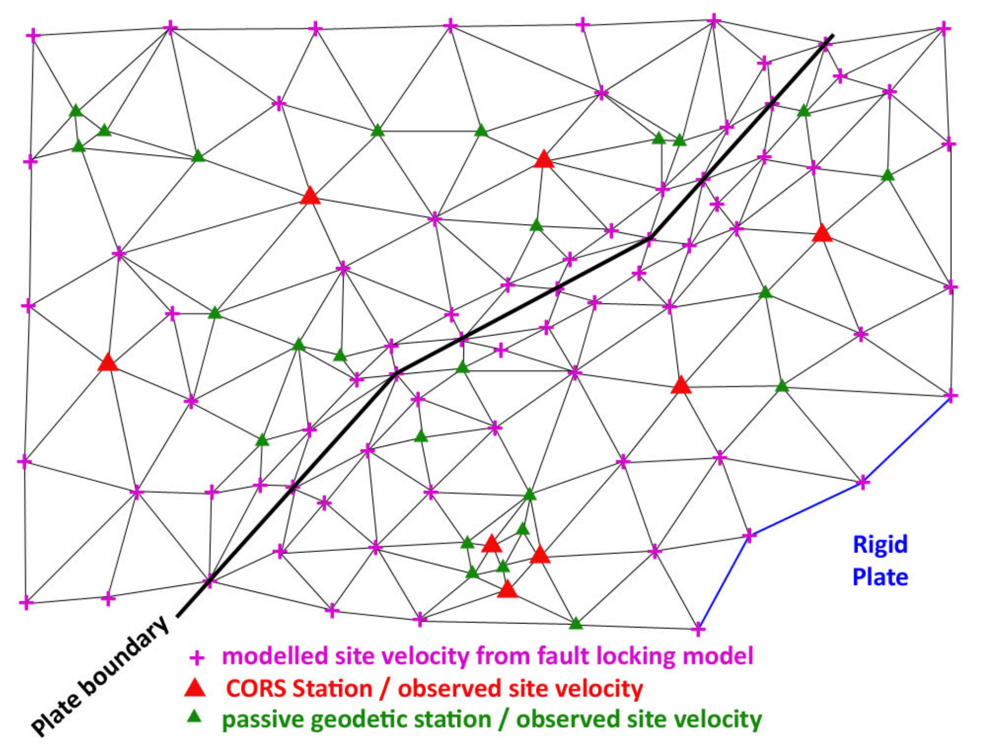
ADM Structure: (4) Composite ADM within deforming zone



Uses rigid plate model (3 parameter) for 97% of the Earth's surface

Modelling and interpolation in deforming zones is constrained by known (measured) ITRF site velocities (e.g. CORS and campaign stations)

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Earthquakes and localised subsidence or uplift

Coseismic and Postseismic deformation should result in a change in coordinates to reflect changes in localised geometry (e.g. fault rupture across existing cadastral boundary)

Deformation patch computed from LiDAR, InSAR, high-res imagery and conventional/GNSS surveys and applied to ADM

Subsidence and uplift should be treated in a fully kinematic way (due to high spatial and temporal variability in affected areas)

To conclude

A survey accurate deformation model linking kinematic ITRF to a static or semi-kinematic local system is essential to maintain integrity of spatial data over time and to support NRTK

Scope for varying resolution deformation models to suit different user requirements

An international standard deformation model format is required to support locally consistent PPP

THANK YOU!