# CORS Network and Datum Harmonisation in the Asia-Pacific Region

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## *CORS Networks in the Asia-Pacific - Challenges*

- *Sparse geodetic infrastructure - datum, CORS distribution, data communications*
- *Surveyors' knowledge, access to, and mastery of GNSS/GPS technology & geodesy*
- *Tectonic deformation & subsidence*
- *Multitude of regional datums (e.g. astro datums & geocentric datums with different reference epochs)*

## CORS Networks in the Asia-Pacific - Benefits

*Significant improvement in efficiency, precision & repeatability*

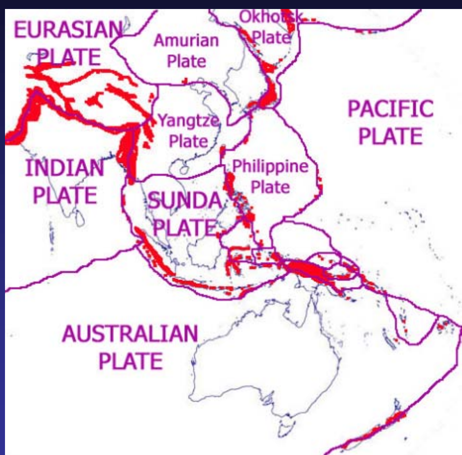
*Legal Traceability for cadastral surveys (e.g. customary land in remote areas)*

*Minimised engineering and environmental risk for resource sector surveys*

*Minimal requirement for dense network of ground marks in tectonically stable areas*

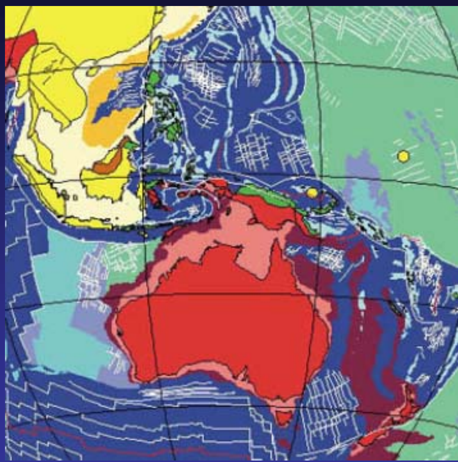
*Improved monitoring of sea level change, volcanoes and other natural hazards*

## APREF Deforming zones & plate boundaries




**Deforming zones highlighted in red**
**(White space is on rigid plate)**

## APREF Regional Tectonic Deformation



Regional deformation in the Asia Pacific Region over the last 10 million years

Hall, R. 2002. Cenozoic geological and plate tectonic evolution of SE Asia and the SW Pacific: computer-based reconstructions and animations. Journal of Asian Earth Sciences, 20 (4), 353–434.

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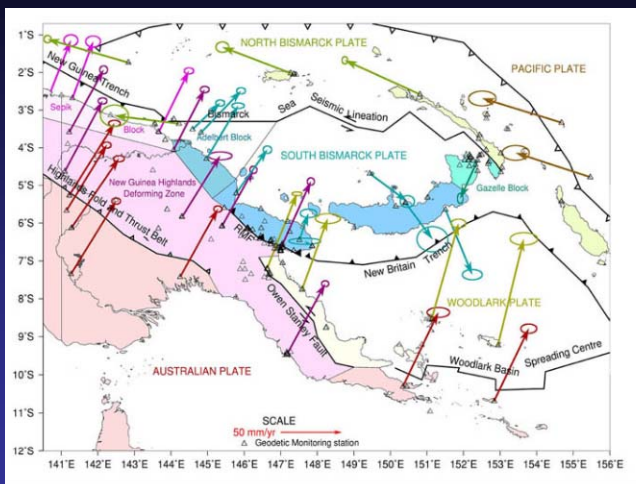
## Complex Tectonic setting in APREF




Microplates & ITRF Site Velocities

e.g. Papua New Guinea

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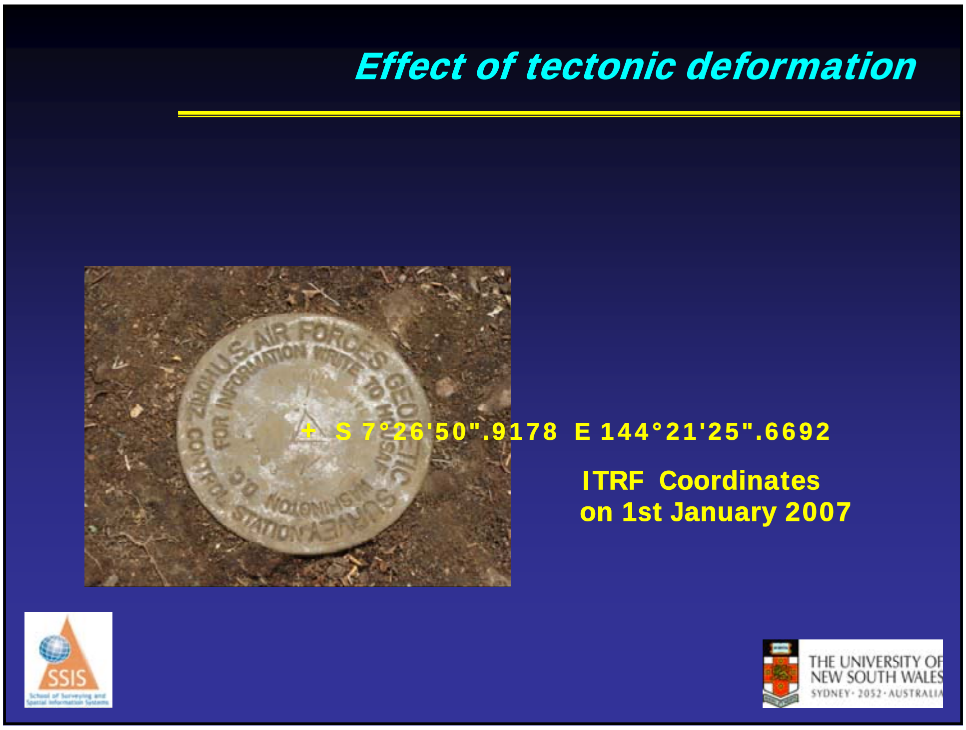
Effect of tectonic deformation
+ S 7°26'50".9178 E 144°21'25".6692
ITRF Coordinates
on 1st January 2007
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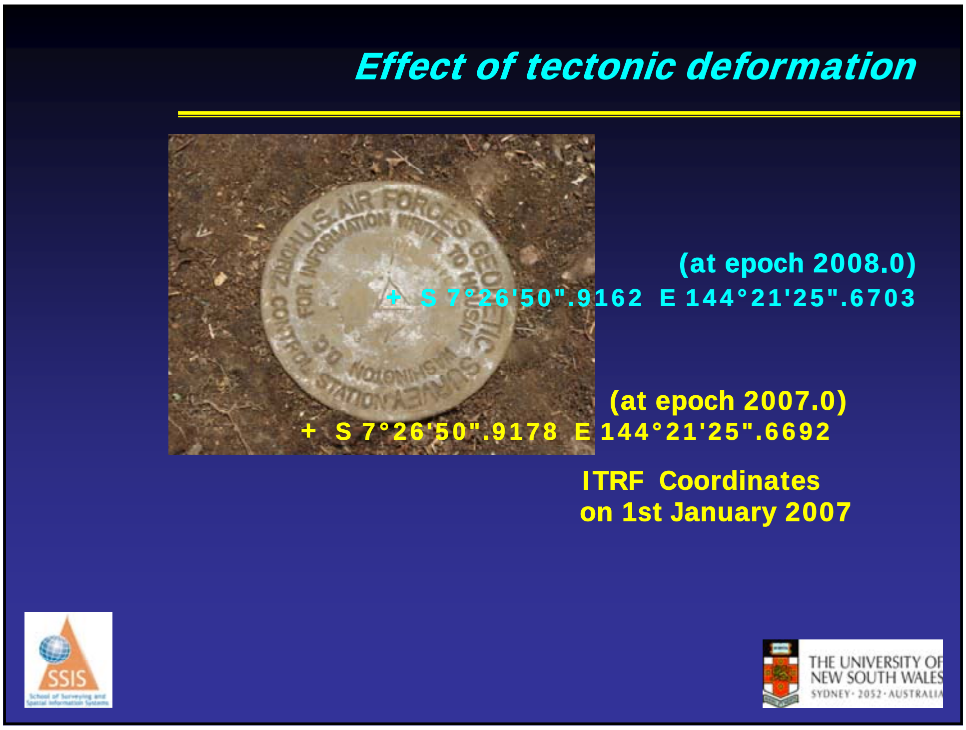
Effect of tectonic deformation
(at epoch 2008.0)
+ S 7°26'50".9162 E 144°21'25".6703
(at epoch 2007.0)
+ S 7°26'50".9178 E 144°21'25".6692
ITRF Coordinates
on 1st January 2007
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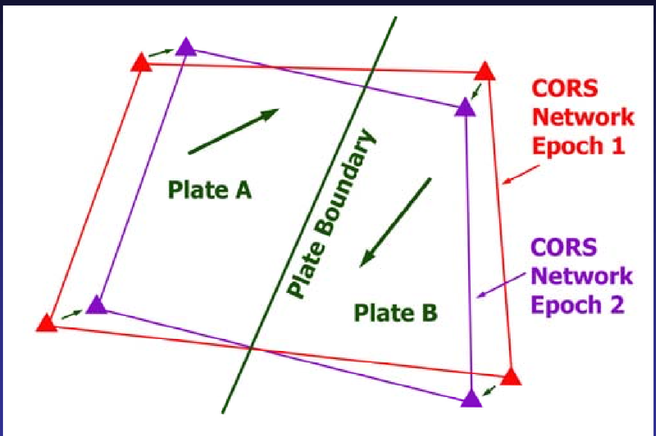
## Coseismic deformation


*$M_w$ 8.0 New Ireland Earthquake*
*Papua New Guinea - 16th November 2000*

## Effect of tectonic deformation - CORS Networks



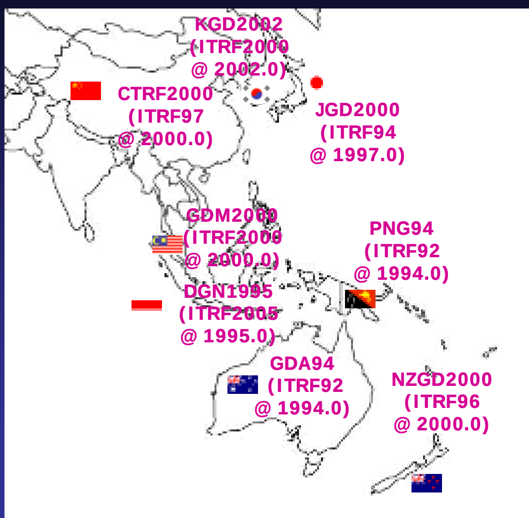
## Benefits of adopting an epoch of ITRF

*Datum will be geocentric (compatability with GNSS orbit solutions)*

*< 3 metre agreement between other geocentric ITRF based datums on decadal scale (OK for 1:20,000+ scale mapping) and navigation*

*simplified GNSS and datum transformations*

## Adoption of ITRF in APREF Countries to date




**No common epoch or realisation across national borders (except AUS-PNG)**

**Regional misalignment ~ 0.5 m between 1994-2002**

## Kinematic, Semi-kinematic or Static?

**Kinematic datum (e.g. ITRF)**
Coordinates change constantly (<8 cm/yr) as a result of global tectonic deformation

**Semi-kinematic datum (e.g. NZGD2000)**
uses a tectonic deformation model to "fix" coordinates at a reference epoch within an internally deforming datum

**Static Datum (e.g. GDA94)**
Datum coordinates "fixed" at a reference epoch - no internal deformation assumed

## Kinematic or Static/semi-kinematic? - Kinematic

**KINEMATIC PROS**

ITRF effectively used as national datum
No velocity or deformation model required with instantaneous coordinates

**KINEMATIC CONS**

Constantly changing coordinates
Difficult to integrate surveys / GIS coordinates made at different times (impossible without deformation model!!)
Legal traceability of coordinates will require epoch and deformation model
Precision Agriculture!!

## Kinematic or Static/semi-kinematic? - Static

**STATIC / SEMI-KINEMATIC PROS**

Coordinates do not constantly change

Integration of surveys at different epochs possible without deformation model

**STATIC / SEMI-KINEMATIC CONS**

Divergence from ITRF as function of time

NRTK algorithm requires transformation from ITRF to static

## Is a dual datum (kinematic & static) feasible?

**Yes!!!**

ITRF used for:
- datum maintenance
- deformation monitoring
- NRTK / CORS orbit analysis
- LiDAR / InSAR processing
- highest precision regional surveys

↓ Transformation / deformation model to link kinematic ITRF to "static" frame ↓

Static / semi-kinematic: used as working datum

AIM: Deformation not "visible" to users

## *What style of transformation should be used?*

***Rigid plate settings (e.g. Australia, Central Pacific Islands, Southern India, Borneo)***

*14 parameter transformation*
*(7 conformal / Bursa-Wolf + rates of change)*
*(can also be used for 3D deformation)*

*4 parameter rigid plate model*

***Deforming zones (e.g. Indonesia, Japan, Papua New Guinea)***

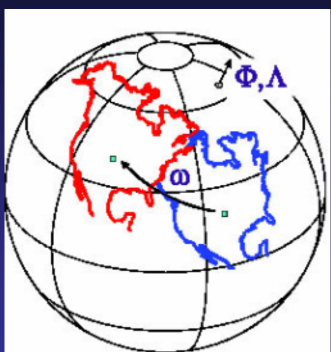
*Fault locking model*

*Finite Element Model*

*Localised rigid plate model*

## *Parameterising rigid plate motion*

**kinematic parameters →** $\Omega_X$ $\Omega_Y$ $\Omega_Z$




**Rigid plate motion defined by Euler pole**

| Plate | Euler pole of rotation | | | Equivalent Cartesian angular velocity | | |
|---|---|---|---|---|---|---|
| | Φ (°) | Λ (°) | ω (°/Ma) | $\Omega_X$ (Rad/Ma) | $\Omega_Y$ (Rad/Ma) | $\Omega_Z$ (Rad/Ma) |
| Amurian | 56.3 | -102.8 | 0.269 | -0.000577 | -0.002543 | 0.003904 |
| **Australia** | **32.4** | **37.4** | **0.628** | **0.007354** | **0.005616** | **0.005874** |
| Eurasia | 56.3 | -95.0 | 0.261 | -0.000263 | -0.002512 | 0.003791 |
| India | 49.8 | 21.8 | 0.614 | 0.006417 | 0.002572 | 0.008188 |
| Pacific | -62.6 | 112.9 | 0.682 | -0.002131 | 0.006052 | -0.010585 |
| Yangtze | 59.4 | -109.7 | 0.316 | -0.000929 | -0.002590 | 0.004658 |

ITRF2005 plate absolute rotation poles
(Altamimi *et al,.* 2007)

**Site Velocity from Plate Model and Location (X,Y,Z)**

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

**Baseline changes usually insignificant within a rigid plate**

## Computing static coordinates in a kinematic system

$$\begin{bmatrix} X_0 \\ Y_0 \\ Z_0 \end{bmatrix} = \begin{bmatrix} X_t \\ Y_t \\ Z_t \end{bmatrix} + \begin{bmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{bmatrix} (t_0 - t)$$

Computing "Static" coordinates at a reference epoch coords from site velocity

➔

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

"Static" coordinates at a reference epoch computed directly from a rigid plate model

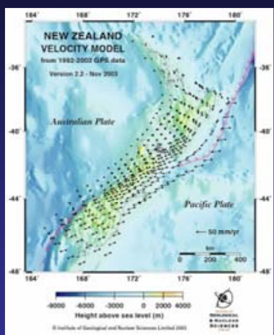
**4 parameters can link a kinematic datum with a static datum (on a rigid plate):**

**$\Omega_X$, $\Omega_Y$, $\Omega_Z$ and $t_0$**

## What about deforming zones?

Static model requires additional parameters

- Fault locking parameterisation required
- Finite element modelling - higher precison (e.g. New Zealand Deformation model)




Sesimic deformation

- usually localised and non-linear
- requires offset parameters at epoch of event and postseismic terms to be parameterised

Rigid Plate models - limited application in rapidly deforming zones

## Focus of current research

*Absolute deformation model*

- Rigid Plate Motion
- Non-linear plate boundary deformation
- Parameterising co-seismic offsets
- Parameterising post-seismic relaxation
- Slow slip deformation

## Practical Steps for CORS - APREF

Tier 1 CORS - Ultra-stable (e.g. IGS)

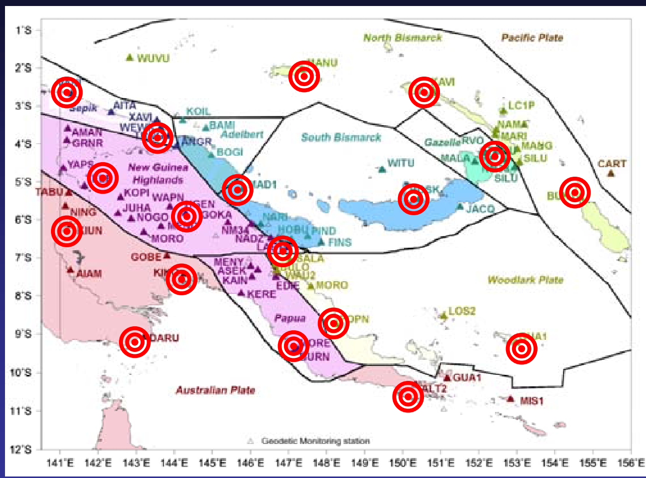
Tier 2 CORS - Datum maintenance

Tier 3 CORS - Masts on buildings etc. (fit-for-purpose)

Stable ground marks - (RMs, campaign style obs., redundancy)
- very important in tectonically unstable areas

Locations: Airports, Mines, Government Offices, Tide Gauges

## Distribution of CORS & Geodetic monitoring




Optimal CORS Station

## Practical Steps for ITRF adoption - APREF

*Several days observations over network*

*Repeat survey at different epoch*

*Adopt nearest whole epoch (e.g. 2011.0)*

*Improve velocity model - by repeat obs.*
*(ITRF velocity precision will improve with time)*

*Observe earlier datum stations -*
*Essential for legacy datum transformation*

*Adopt EGM2008 with local*
*height datum geometric correction*

## *To summarise*

- semi-kinematic realisation of ITRF used as basis for a working national datum
- kinematic ITRF - used for NRTK / datum maintenance
- Absolute deformation model to connect ITRF and local
- Good distribution of CORS and ground marks
- Connection to older datums reqd. for transformation parameter estimation
- Fully kinematic datum <u>not recommended</u> as a working datum - too many spatial data management issues


**Thank you!**