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


Complex Tectonic setting in APREF

Microplates & ITRF Site Velocities

e.g. Papua New Guinea
Effect of tectonic deformation

ITRF Coordinates on 1st January 2007

\[ S 7°26'50''.9178 \ E 144°21'25''.6692 \]

(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
Coseismic deformation

*Figure: Mw 8.0 New Ireland Earthquake, Papua New Guinea - 16th November 2000*

Effect of tectonic deformation - CORS Networks

*Diagram: Effect of tectonic deformation - CORS Networks*
Benefits of adopting an epoch of ITRF

Datum will be geocentric
(compatibility 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

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**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

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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)

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 ➜ $\Omega_X \quad \Omega_Y \quad \Omega_Z$

Rigid plate motion defined by Euler pole

Baseline changes usually insignificant within a rigid plate
Computing static coordinates in a kinematic system

Computing “Static” coordinates at a reference epoch coords from site velocity

\[
\begin{bmatrix}
X_0 \\
Y_0 \\
Z_0
\end{bmatrix}
- \begin{bmatrix}
X_t \\
Y_t \\
Z_t
\end{bmatrix}
\left(t_0 - t\right)
\]

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

\[
\begin{bmatrix}
X_0 \\
Y_0 \\
Z_0
\end{bmatrix}
- \begin{bmatrix}
X_t \\
Y_t \\
Z_t
\end{bmatrix}
= \begin{bmatrix}
\Omega_{2Z} - \Omega_{2X} \\
\Omega_{1Z} \\
\Omega_{1X} - \Omega_{1Y}
\end{bmatrix}
(t_0 - t) \times 10^6
\]

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 precision
(e.g. New Zealand Deformation model)

Seismic 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

![Map of CORS stations](map.png)

- 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 not recommended as a working datum - too many spatial data management issues

Thank you!