Case Study for Papua New Guinea

Dr. Richard Stanaway
Association of Surveyors of Papua New Guinea
(ASPNG)


Thailand
Vietnam
South
China Sea
Catanduanes
Island
Catanduanes
Andaman
Sea
Cambodia
Philippines
Visayas
Kabisayaan
Cebu
Leyte
Island
Leyte
Bohol
Sulu Sea
Mindanao
Basilan
Island
Basilan
Malaysia
Celebes
Sea
Singapore
Bismarck
Sea
Indonesia
Java Sea
Banda Sea
Papua New
Guinea
Arafura
Sea
Solomon
Sea
Timor Sea
Coral Sea
Australia

Motivation for PNG national reference frame modernisation

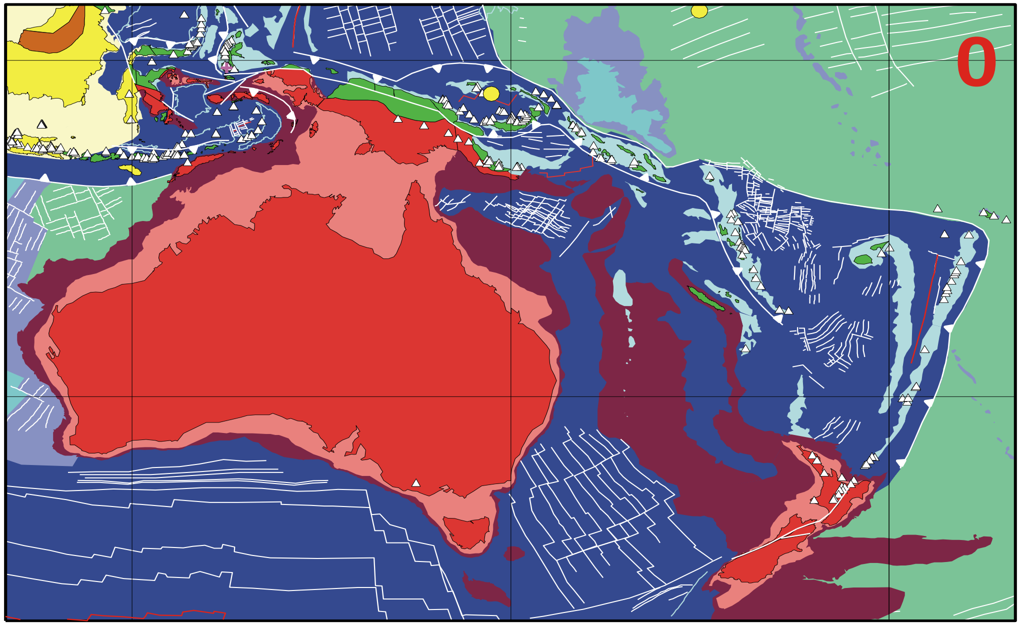
Current national datum is PNG94 (ITRF92 at epoch 1994.0) - now almost 29 years from reference epoch. Co-realised with GDA94 in neighbouring Australia

Coordinates of "fixed" points (e.g. geodetic control, cadastral mapping) now differ by up to 2.5 m from current ITRF coordinates (e.g. using GNSS-PPP)
Highly complex and variable tectonic setting precludes use of parametric transformations and plate motion models

Very many significant coseismic displacements (up to 5 metres) since 1994 that necessitate coordinate updates in affected areas (relative to original realisation)

Requirements for common coordination with Indonesia (border pillar monuments) and Australia (Torres Strait Protected Zone - TSPZ) which now uses GDA2020 (ITRF2014 at epoch 2020.)

Papua New Guinea's Tectonic Setting

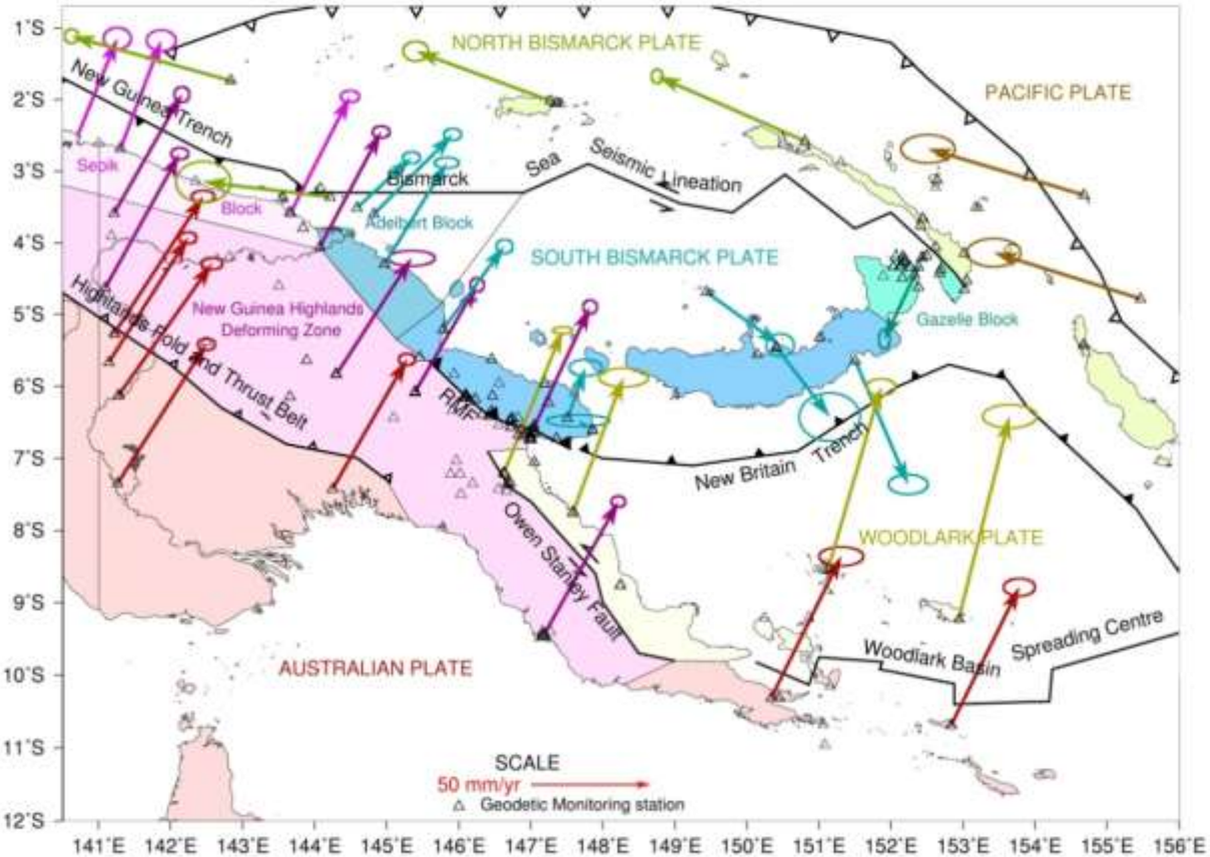


← Millions of Years b.p.

← "paleo" ECEF/TRF

From Hall, R. 2002. Journal of Asian Earth Sciences, 20 (4), 353–434.

Papua New Guinea – tectonic plates and velocities

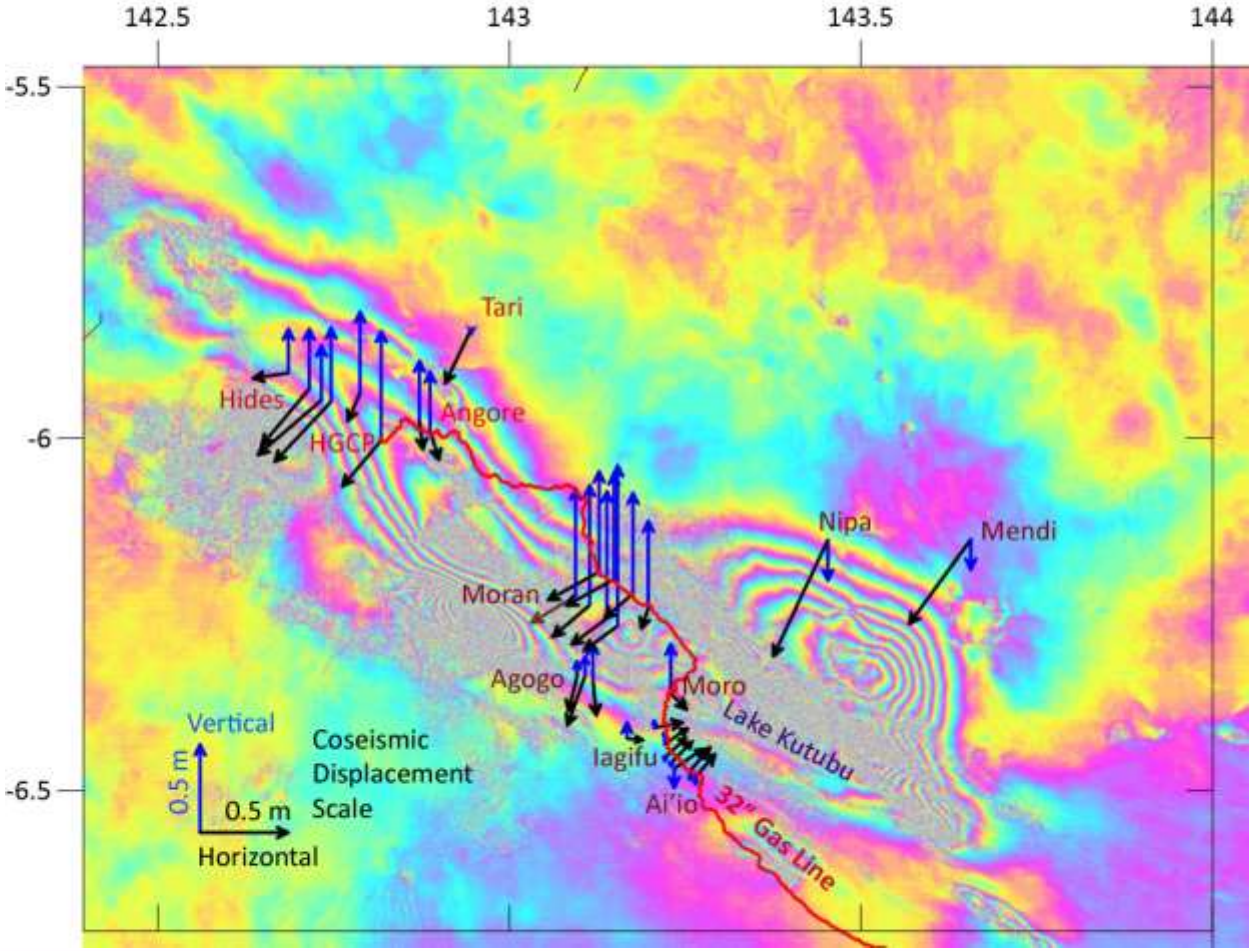


ITRF2014/IGS velocities
(coordinate change per year)
In PNG
(Stanaway et al. 2004)


Telstra
12:09
46%
earthquake.usgs.gov
USGS
MENU
M 7.6 - 66 km E of Kainantu, Papua New Guinea
2022-09-10 23:46:57 (UTC)
6.256°S 146.469°E
90.0 km depth
Interactive Map
Contributed by US 4

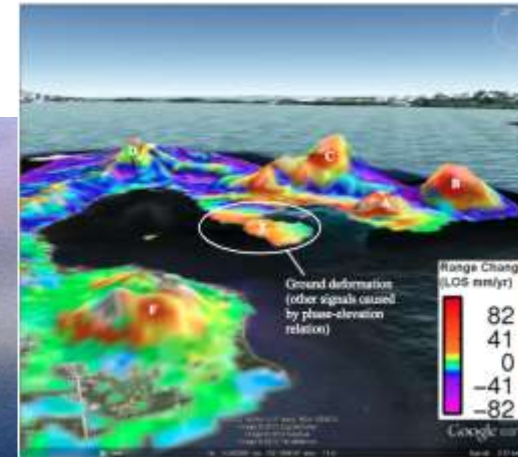
Just today!

Earthquake (coseismic) displacements



2018 PNG Highlands M_w 7.5
Earthquake sequence
displacement
Observed by GNSS and Insar
(ALOS2 Interferogram, Jaxa, 2018)

Volcanic hazards and displacements



Uplift rates from InSar

Twin volcanic eruptions of Vulcan (L) and Tavurvur (R), Rabaul, September 1994

A new datum for PNG – PNG2020

PNG2020 will be aligned with ITRF2020 at epoch 2020.0
(< 4 mm difference from ITRF2014 at epoch 2020.0)

Better than 0.25 m agreement with ITRF PPP positioning at end of 2022

PNG2020 Deformation model:

ITRF2020 based velocity grid for time-dependent secular transformations between ITRF2020 and PNG2020 (primarily to support PPP usage)

Coseismic and postseismic displacement grids developed after significant earthquakes to enable coordinate updates after earthquakes and spatial transformations across earthquake events

PNG2020 components

Physical infrastructure
(e.g. CORS, PSMs and their maintenance)

Access
(station information, coordinates, RT data stream, CORS Rinex data, online processing)

Tools
(models, transformations, guidance notes, geodetic registry and GIS configurations)

PNG2020 – physical infrastructure - CORS

Continuously Operating Reference Stations (CORS)

A physical monument (GNSS antenna mount) on which a GNSS antenna connected to a continuously operating receiver is attached

CORS around Papua New Guinea

PNG - CORS network expansion

Ideally there should be a CORS in each provincial capital, mine and development site where extensive land surveys are conducted.
Single-base RTK (or Networked RTK using multiple CORS in major towns)

Private CORS networks (licence/permit for external access?)

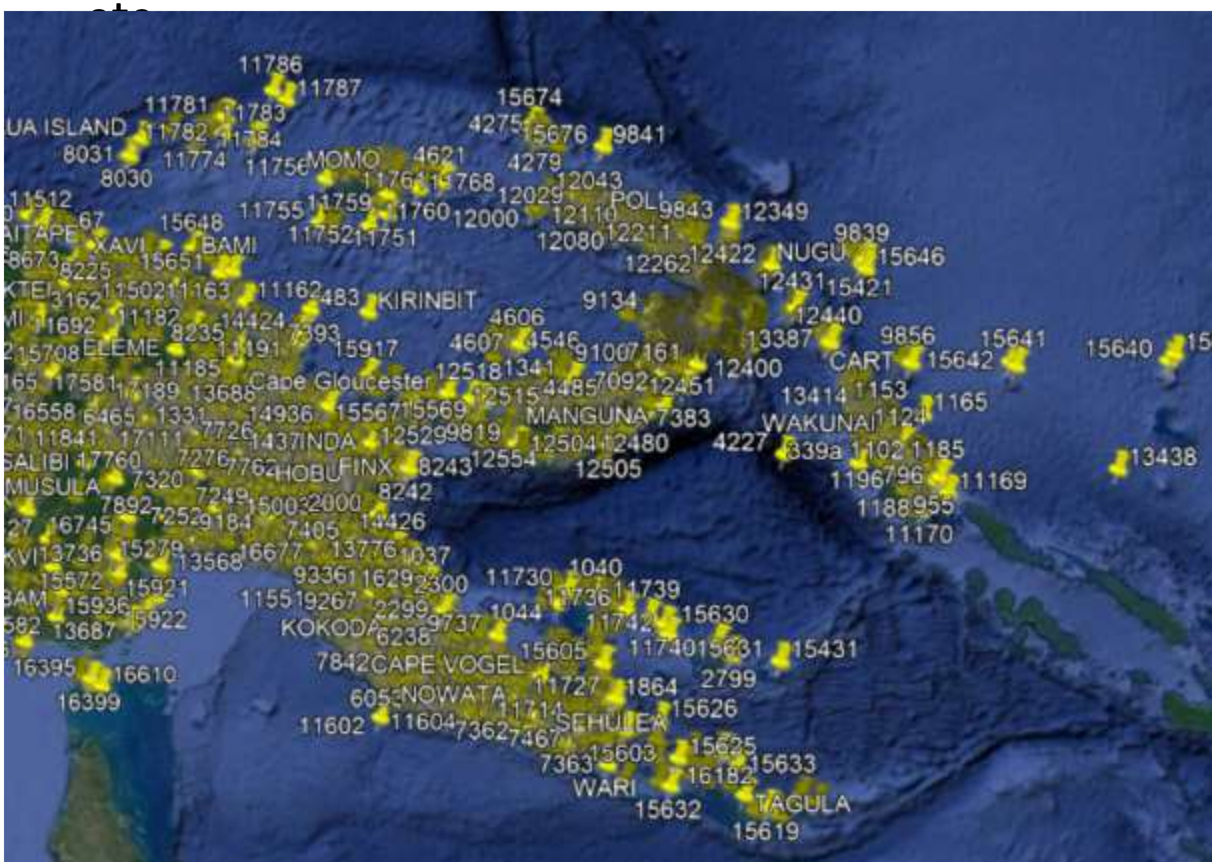
Subscription CORS services (e.g. SmartNET, AllDayRTK, VRSnow)

Continuous geohazard monitoring (volcanic hazards)

Option for low cost CORS (e.g. STONEX, ARDUSIMPLE, COMNAV) to improve network density and access.

PNG2020 – physical infrastructure – passive network

~15,000 brass plaques, bolts, star pickets and pins in concrete, pillars etc.



PNG2020 passive geodetic network

Permanent Survey Marks (PSM) – still form the backbone of PNG's geodetic infrastructure due to sparse CORS network.

Still required for terrestrial survey connections to datum (total station, TLS surveys), non-CORS referenced GNSS RTK and rapid-static GNSS surveys, Digital Cadastral Database (DCDB) , monitoring of tectonic and other ground deformation, control and validation of imagery (drone based photogrammetry).

Calibration and configuration validation of GNSS equipment and monitoring of CORS and tide gauges by site ties.

Many thousands of PSMs have been destroyed, are difficult to locate or are in impractical locations (e.g. classical mountain top trigonometric stations).

Requirements for PNG2020 densification

A definite need to extend/densify the passive network to suit current and future positioning requirements.

Accessible and secure locations with stable ground and good sky visibility with permanent aerial targets for imagery/remote sensing control (airports landside and airside, port facilities near tide gauges, inside government compounds, universities, schools, mines, plantations)

Urban areas urgently require attention due to fast attrition of PSMs in recent years – (Jerry Paraka, Unitech, 2021 thesis)

PNG2020 – access – CORS data streaming

At present limited effective real-time data streaming (e.g. NTRIP) from CORS in PNG. 4G Internet is now widely available and generally reliable but power supply is erratic (requires high-performance UPS and standby generators)

RT networks are all private (e.g. mine sites, oil palm plantations)

Office of the Surveyor-General (OSG) does not currently have the resources or budget to operate RT networks, so there is scope for subscription based CORS services (e.g. SmartNET, AllDayRTK, VRSnow)

LAE2 will soon have a RT data stream (RTCM3.2) accessible from Geoscience Australia's NTRIP server.

Name	Server Address	Mountpoint	Data Type	Status	Start Time	Data Size	Operation
LAE2_RT	ntrip.data.gnss.ga.gov.au:2101	LAE200PNG0	RTCM32	transmitting	2022-09-07 15:28:16	0 B	Edit Start Stop

Rinex Data - portal

https://data.gnss.ga.gov.au

Australian Government Geoscience Australia

GNSS Data Repository v1.2.0

Search for RINEX Files

All RINEX data is stored in gzip format; all observation data is also Hatanaka compressed. For API documentation and other access methods (such as SFTP), see GNSS Data Repo Docs.

GNSS Sites *: LAE1

RINEX Version *: (•) 2 ( ) 3

File Type *: ☐ Meteorological ☐ Navigation ☑ Observation

File Period *: ☑ Daily 30-second data ☐ Hourly 30-second data ☐ High-rate data

Start Date (UTC) *: 2022-06-01 00:00:00

Search

Download RINEX files (6 files found)

Items Per Page 10 — Download

☐	File Name	Site	Start Date	File Type	File Period	RINEX Version
☐	lae11720.22d.gz	LAE1	2022-06-21 00:00:00	Obs	Daily	2
☐	lae11730.22d.gz	LAE1	2022-06-22 00:00:00	Obs	Daily	2
☐	lae11740.22d.gz	LAE1	2022-06-23 00:00:00	Obs	Daily	2
☐	lae11750.22d.gz	LAE1	2022-06-24 00:00:00	Obs	Daily	2
☐	lae11760.22d.gz	LAE1	2022-06-25 00:00:00	Obs	Daily	2
☐	lae11770.22d.gz	LAE1	2022-06-26 00:00:00	Obs	Daily	2

Rinex 3 data (30 second) epoch available from the International GNSS data service (IGS) and Geoscience Australia (GA) GNSS Data Repository

PNG2020 – access – geodetic control database

UN-GGIM and FAIR (findable, accessible, interoperable and reusable) principles recommend:

Open and free access to national geodetic control information.

PNG geodetic control information (e.g. coordinates) is currently only available on request and photocopies of PSM location sketches are available for a fee from the National Mapping Bureau.

There is an urgent need to have the geodetic control database and PSM data made publicly available from the web (e.g. searchable database and Google kml) at no cost

The ASPNG can also host this type of service if requested by OSG.

Land Information New Zealand (LINZ) has a good template for this service

Mobile web Apps (PSM finders) are also now widely used by surveyors

PNG2020 – geodetic observations

Currently underway since 2018 (delays due to covid-19 pandemic and 2022 general election)

Directed by Office of the Surveyor General (OSG) geodetic section

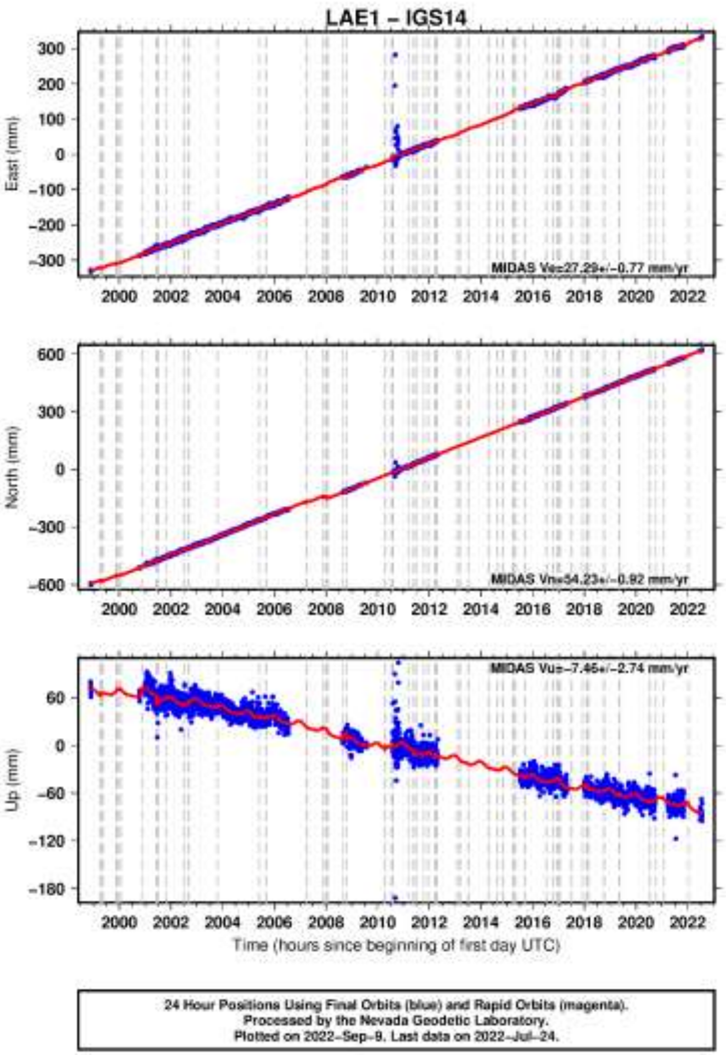
Department of Surveying and Land Studies – Unitech, Rabaul Volcano Observatory, mining companies, seismic surveyors and many private sector surveyors freely providing valuable GNSS static data to improve geodetic network and take pressure off OSG budget.

Big GNSS survey campaign will commence in late 2022 for Lae regional seismic study (Morobe province, Madang, EHP, WNB) – collaboration between Geoscience Australia, OSG, Unitech – funded by DFAT Australia

PNG/Indonesian border survey (NMB and OSG with Indonesian counterparts)

Missing gaps (e.g. Kavieng, Manus, Daru, Popondetta) to complete survey in early 2023 (OSG) – also in conjunction with NMSA TG survey.

PNG2020 progress

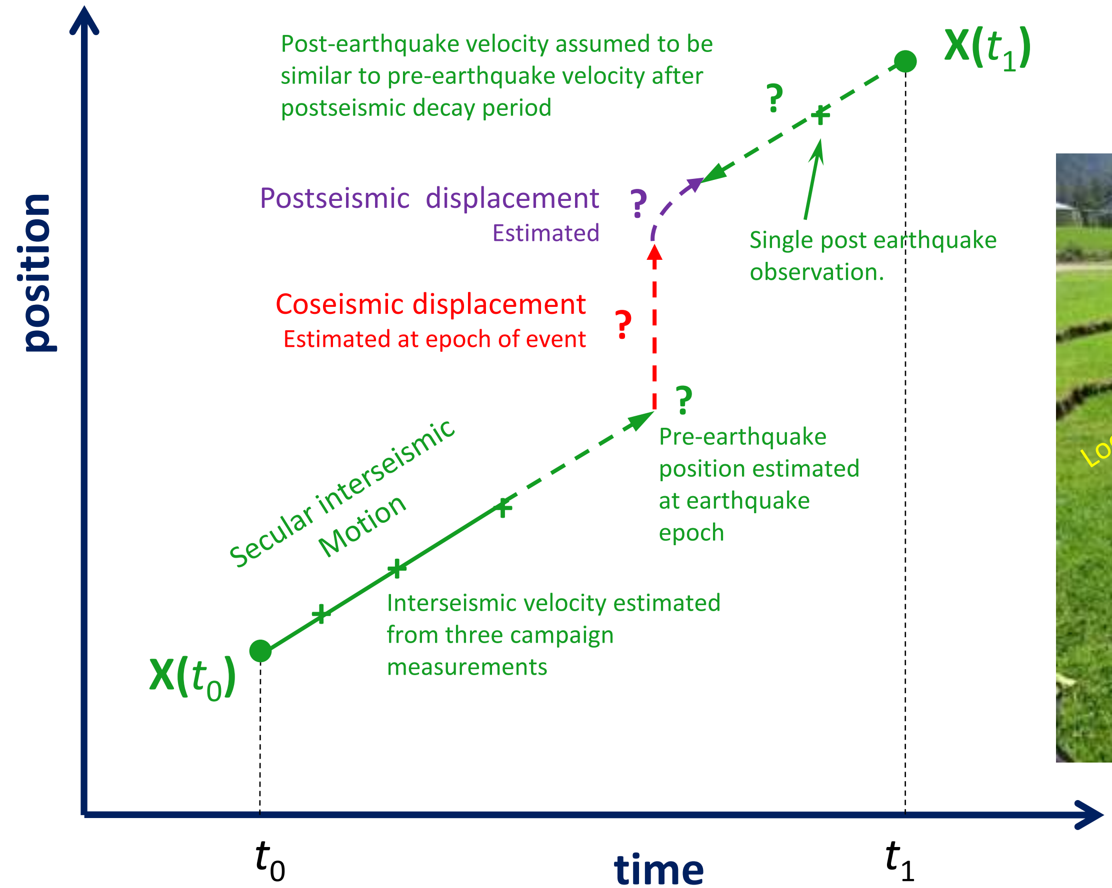


Site velocity estimation

All PNG GNSS static data (dual-frequency) processed in an ITRF2014/2020 RF will be stacked to form a site time series. From this the site velocity and other offsets (e.g. coseismic, postseismic decay) can be estimated. Noise model (to model out seasonal signals) may be applied

The site velocity is used to estimate the coordinates at any defined epoch or reference epoch (2020.0 for PNG2020)

Some issues with velocity estimation using campaign data in seismically active regions



PNG ITRF2020 velocity grid (deformation model)

Velocities initially used to estimate microplate rotation models by inversion of velocities and plate boundary elastic strain correction to estimate pole of rotation (using approach used by Achraf Koulali, Paul Tregoning and Laura Wallace in earlier geodynamics studies)
2nd order residuals interpolated by a kriging process to estimate plate boundary strain correction grid.

The correction grid will be combined with the interseismic velocity grid generated from each microplate rotation model to form the final velocity grid.

Grid spacing 0.1 degree over PNG and will be provided in csv, NTv2, NetCDF(GGXF) and other well used formats for ingestion into positioning and GIS software.

PNG2020 transformation grids

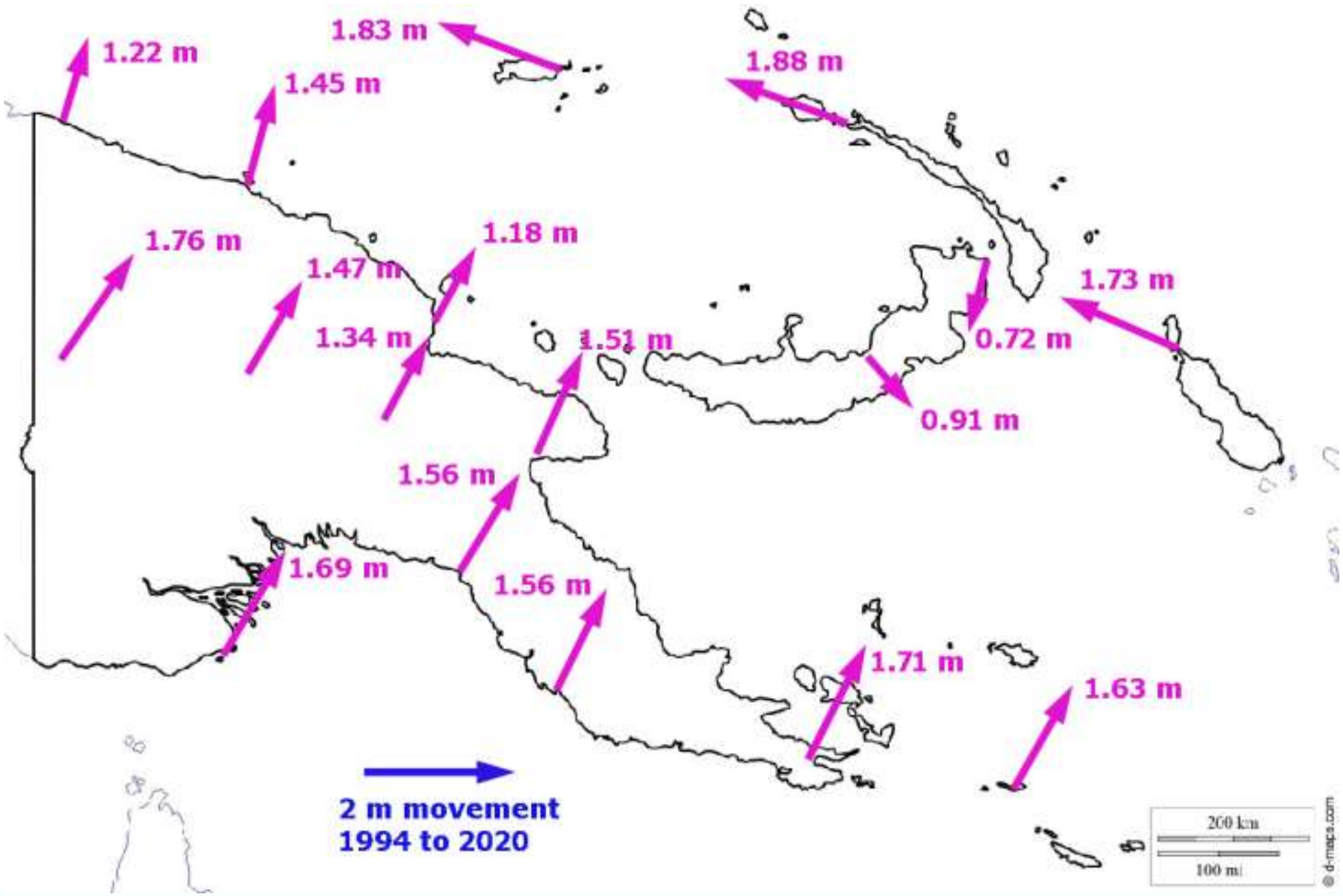
In addition to the time-dependent ITRF2020 to PNG2020 transformation grid (using bilinear interpolation of the velocity grid) the following transformation grids will be developed:

PNG94(2022) to PNG2020(2022) (in csv, NTv2, NetCDF and GeoTIFF)
This transformation grid will use the latest adjustment of PNG94 that includes known coseismic displacements between 1994 and 2022.

PNG94(1994) to PNG94(2022) (in csv, NTv2, NetCDF and GeoTIFF)
This transformation grid models known distortions of PNG94 and coseismic displacements between 1994 and 2022.

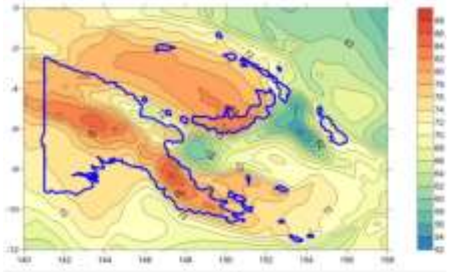
AGD66 to PNG94(1994) and **AGD66 to PNG2020(2022)** grids may also be developed to support transformation of legacy spatial data

PNG94 to PNG2020 coordinate differences



PNG2020 geoid model

The imminent release of EGM2020 is proposed to be used as the basis of a new geoid model to replace PNG08 (a provisional geoid model from 2011) to enable MSL estimation from GNSS in PNG.



Offsets between the EGM2020 geoid surface and MSL observed at recently installed tide-gauges around PNG (NMSA) will be used to develop an MSL corrected model due to large Mean Dynamic Topography (MDT) offsets in warm tropical seas (up to 1.5 metres in PNG) – (Curtin University, Perth?)

Released in csv and binary formats (e.g. GeoTIFF) used with widely used positioning equipment and positioning software.

Further steps ...

Gazettal – PNG Government Gazette

Online GNSS post-processing service for PNG
Request Geoscience Australia to provide PNG2020 (and PNG94) coordinates in AusPOS (online GPS processing service) for data submitted with PNG's territorial limits and EEZ. Alternatively, a PNGpos can be developed.

Geodetic registry submission and configurations
Work closely with geodetic registries and providers of GIS and positioning services to ensure correct implementation of PNG2020 and related transformation grids.

Guidance notes for PNG2020 use

Tenku tru!

Rabaul – Papua New Guinea (Richard Stanaway, September 2022)