PNG2020
A new geodetic datum for PNG

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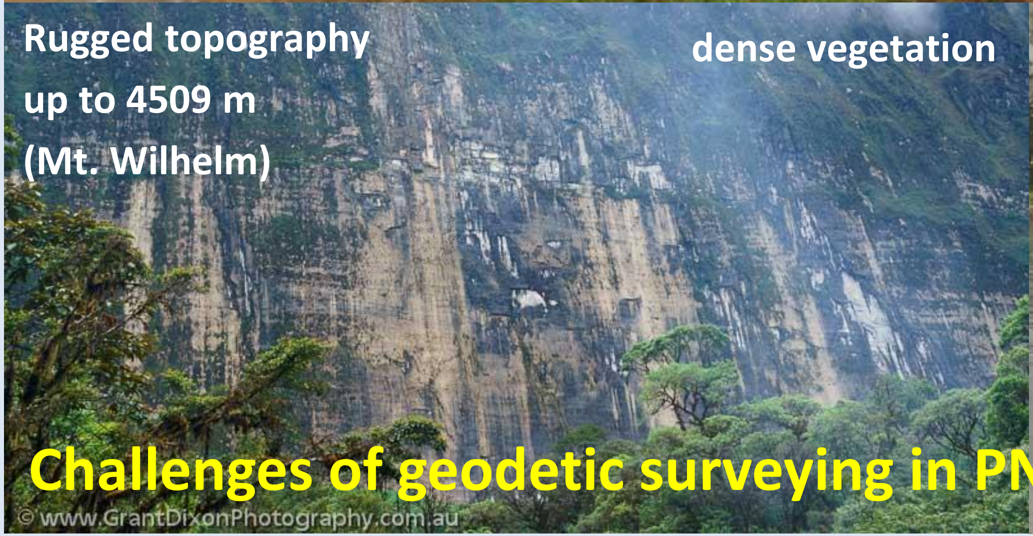
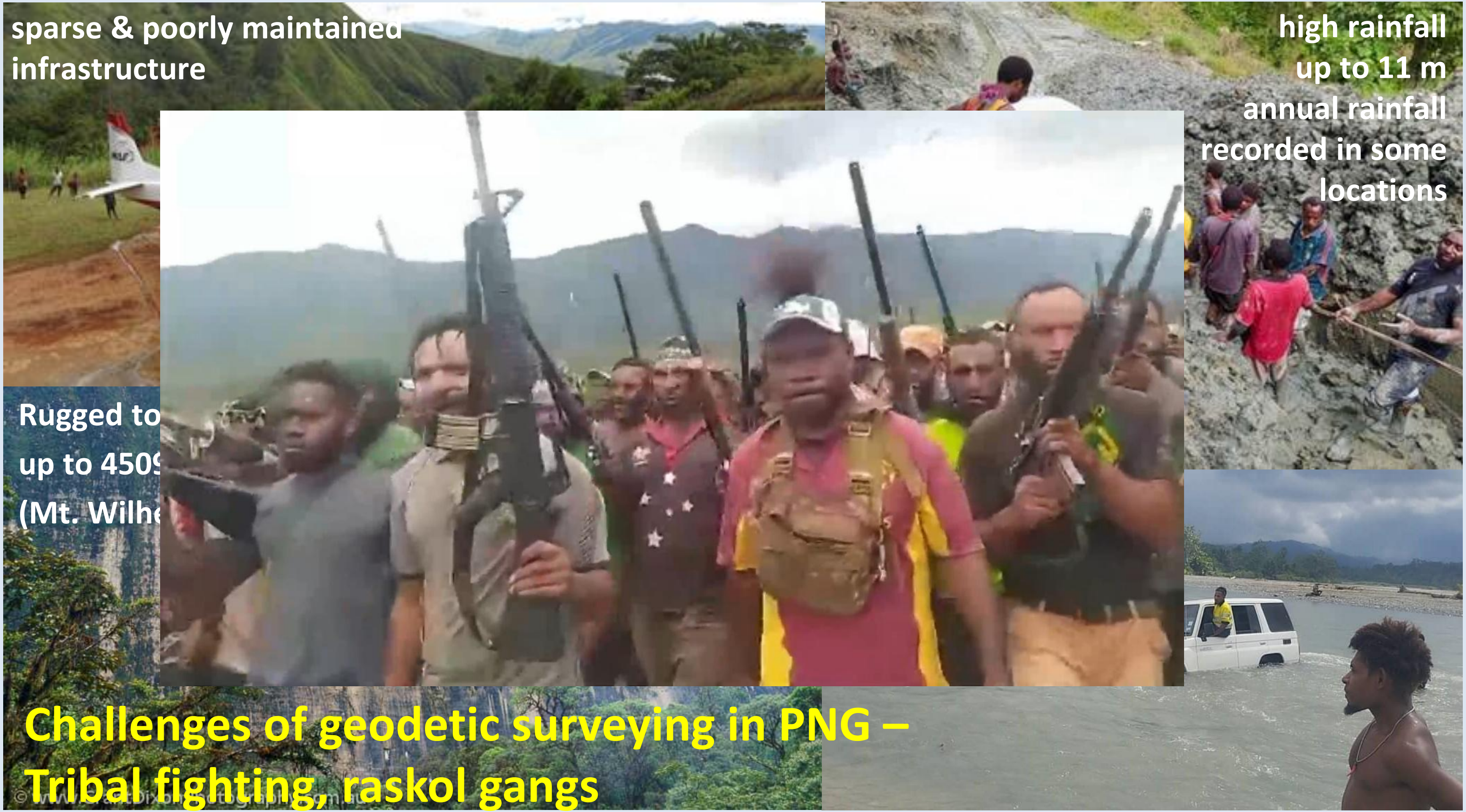
United Nations Global Geodetic Centre of Excellence Asia-Pacific Geodesy Workshop, 30 June – 4 July, Bangkok, Thailand

Papua New Guinea

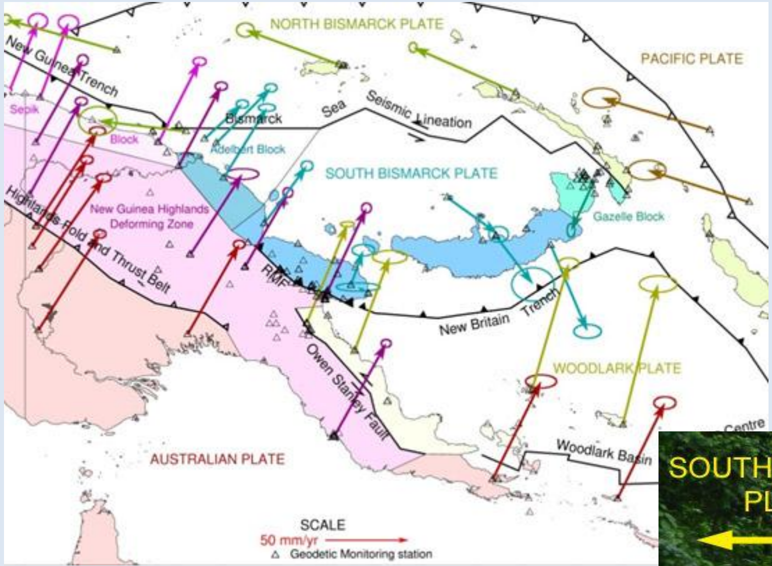
Culturally diverse with 840 living languages

Challenges of geodetic surveying in PNG



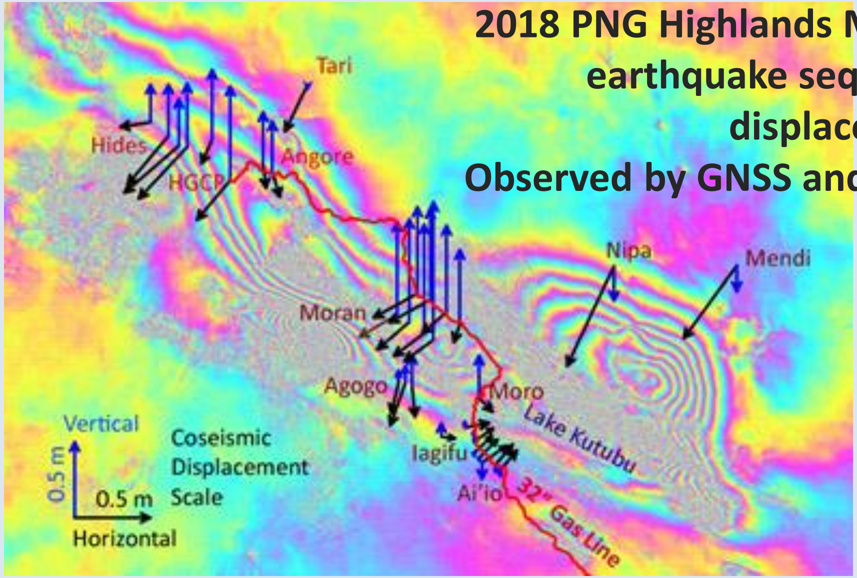

sparse & poorly maintained infrastructure
high rainfall up to 11 m annual rainfall recorded in some locations
Rugged to
up to 450
(Mt. Wilhe
Challenges of geodetic surveying in PNG –
Tribal fighting, raskol gangs

Challenges with plate tectonics and geohazards in PNG



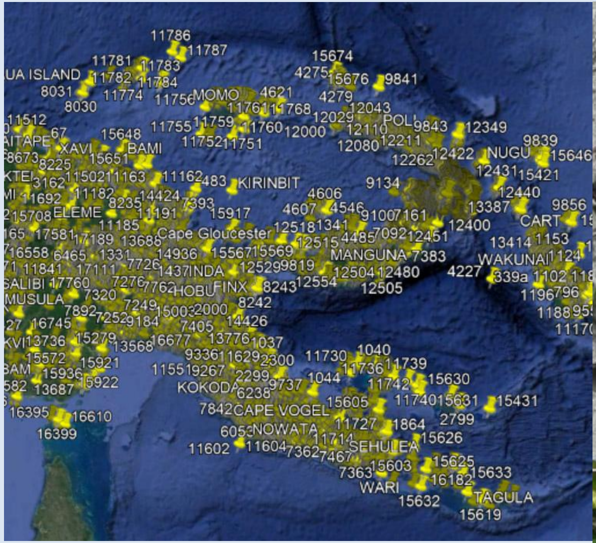
ITRF/IGS velocities in PNG (coordinate change per year)
(from Stanaway et al. 2004)

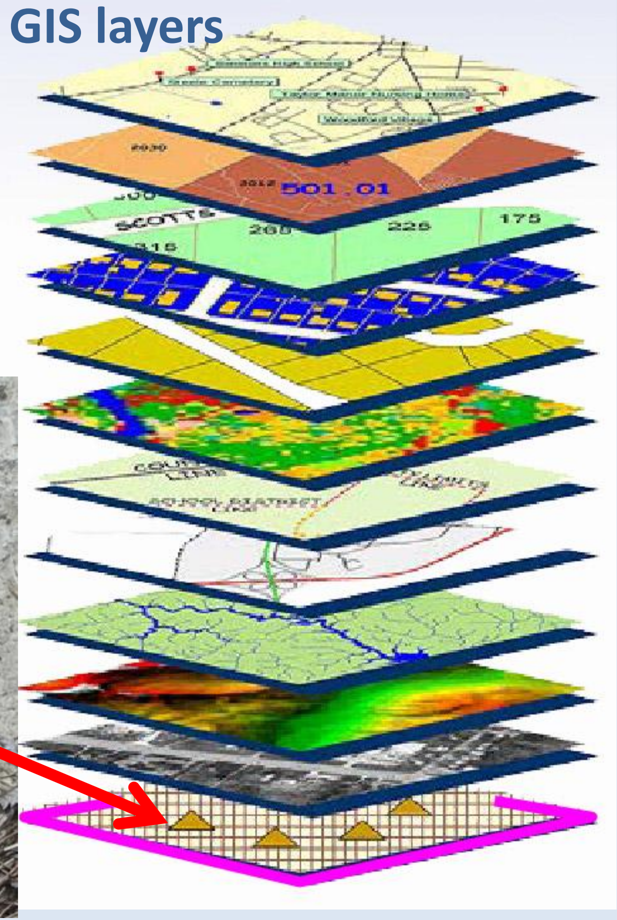
2018 PNG Highlands M_w 7.5 earthquake sequence displacement
Observed by GNSS and Insar

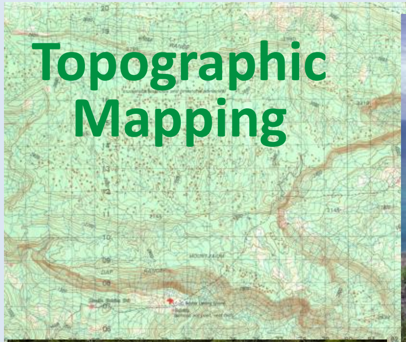


(ALOS2 Interferogram Jaxa, 2018 & Stanaway et al., 2022)

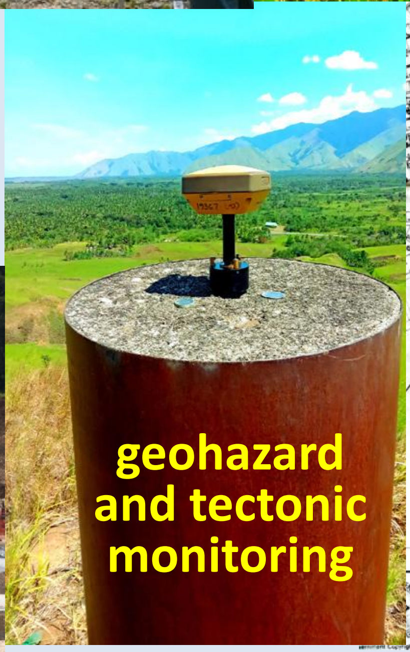
<u>alignment</u> of spatial data is underpinned by geodetic control (Permanent Survey Marks - PSM)

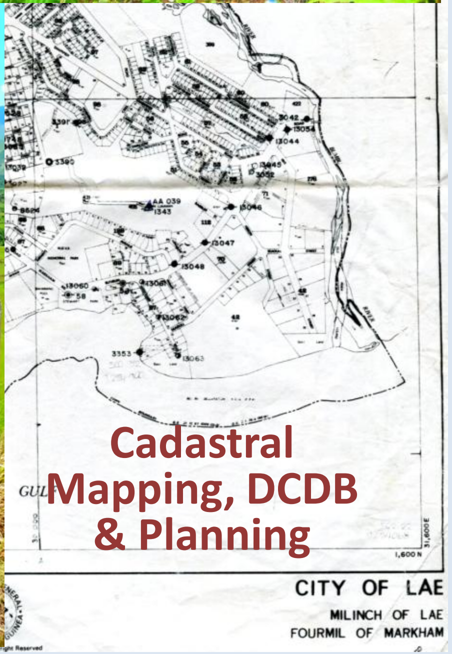






Importance of the PNG geodetic network





PNG94 geodetic datum - zero order geodetic network

(3 cm 2D precision 95% CL)

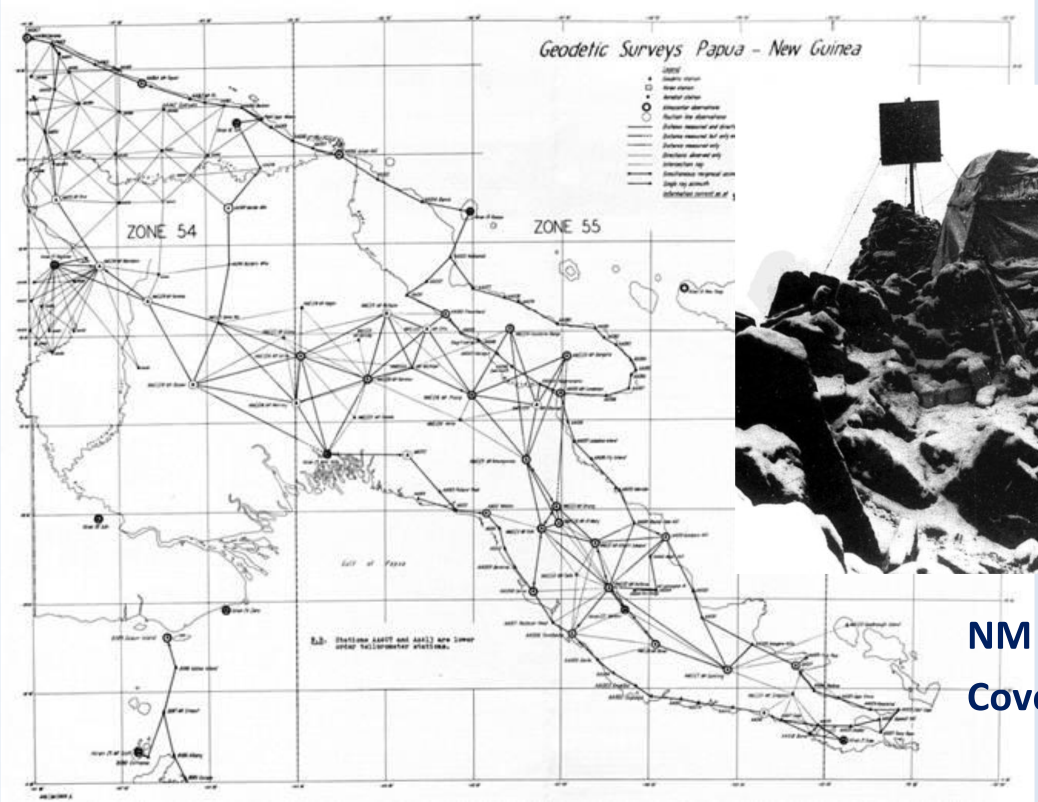
Realised as ITRF92 at epoch 1994.0 - Co-realised with GDA94 in Australia (Morgan et. al, 1996)

Site ID	Site Name	Monument number	PNG94 Latitude	PNG94 Longitude	PNG94 Ellipsoidal Height
MORE	NMB TOWER GPS	PSM 15832	-9°26'02.76968"	147°11'12.20017"	116.610
AIAM	AIAMBAK	PSM 9550	-7°20'51.81934"	141°16'01.44646"	95.465
MIS1	BWAGAOIA AIR	PSM 9195	-10°41'19.90490"	152°49'58.93878"	87.456
GOKA	GOROKA	PSM 9833	-6°04'53.07151"	145°23'30.44618"	1664.580
ALT2	GURNEY	PSM 9538	-10°18'37.50877"	150°20'18.09080"	94.871
KAVI	KAVIENG AIR	PSM 9513	-2°34'53.06528"	150°48'22.53578"	78.828
KIKO	KIKORI AIRPORT	PSM 5583	-7°25'24.65305"	144°14'55.76611"	88.965
MAD1	MADANG	GS 15495	-5°12'41.28824"	145°46'56.19305"	73.293
MANU	MANUS SECOR	PSM 9522	-2°03'02.29337"	147°21'37.63577"	129.751
MEND	MENDI	PSM 3507	-6°08'36.73422"	143°39'22.16540"	1815.154
9799	UNITECH SPORTS	PSM 9799	-6°40'16.96985"	146°59'52.37457"	130.389
VANI	VANIMO DOPPLER	PM 63/1	-2°41'05.28039"	141°18'15.65564"	80.516
NM34	WANKKUN	PSM 15029	-6°08'52.07208"	146°04'52.44226"	510.015
WUVU	WUVULU ISLAND	PSM 15456	-1°44'07.59465"	142°50'10.07846"	79.056

older - Australian Geodetic Datum 1966 (AGD66)

(0.9 m precision 95% CL & ~ <u>200 m</u> different from PNG94, WGS84, ITRF!!)

Superseded by PNG94
but still in use.
(e.g. PNG *Oil and Gas* Act and mining projects started pre-2001)



NM J 19 Mt Wilhelm
Covered by snow

GNSS CORS in PNG

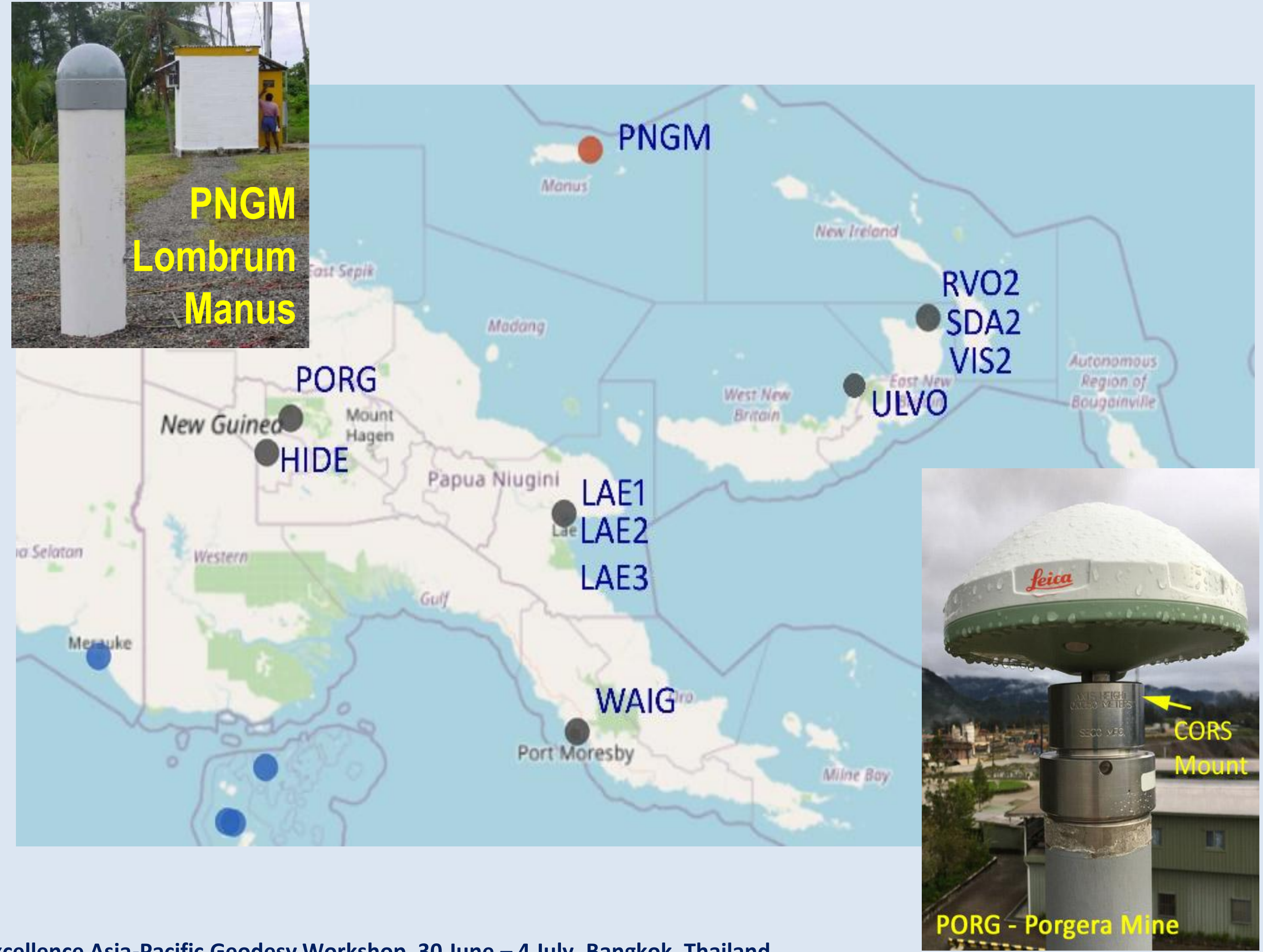
2 IGS stations
LAE1 and PNGM

4 APREF stations
RVO2, WAIG, PORG & HIDE

4 National CORS
LAE2, ULVO, SDA2, VIS2

1 Commercial CORS
LAE3 AllDayRTK/Theodist

Private CORS networks (e.g. Mines, Oil Palm)



PNG94 is already “age challenged”

PNG94 is now over 31 years old (reference epoch)

Users of precise GNSS (and even handheld GNSS/GPS) see differences between GPS coordinates (WGS 84 or ITRF2008, ITRF2014, ITRF2020) and PNG94.

This difference is due to ~ 2 metres of tectonic displacement in PNG since 1994 (secular interseismic displacement between 1994 and 2025) and

- 3542 M_w 5.0 and larger earthquakes since 1994 (< 30 cm displacement)
- 115 M_w 6.5 and larger earthquakes since 1994 (< 1m level displacement)
- 14 M_w 7.5 earthquakes since 1994 (1-5 metre displacement)

Significant distortions now in the PNG94 network that exceed many surveying and positioning tolerances. It is increasingly difficult to use a site velocity model to estimate PNG94 coordinates from current ITRF coordinates from precise point positioning or IGS network GNSS/GPS solutions (e.g. AusPOS, NRCan-PPP).

PNG2020 a new semi-kinematic datum for PNG

The PNG Government commenced development of PNG2020 in May 2024 to supersede PNG94

Static component:
ITRF2020 at epoch 2020.0
(1st January 2020 reference epoch) – closely aligned with GDA2020 in Torres Strait

Kinematic component:
ITRF2020 at epoch *yyyy.yyy*

Velocity model (grid)
to transform between ITRF2020 and PNG2020

Support from other sectors and agencies is essential!

Government

Academic

Private Sector Surveyors

Resource Sector

Geoscience Australia through DFAT provided financial support for a major geodetic survey of the Lae seismic zone and region between 2022 and 2024.

Australian Government

Geoscience Australia

PNGAus Partnership

Four geodetic capacity building workshops were conducted in Lae and Port Moresby in late 2022 funded by GA/DFAT.

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Lae Seismic Zone GNSS survey

PNG2020 station and observation priorities

1. Geodynamic monitoring stations (to improve tectonic velocity model)
2. Urban survey control (cadastral, construction, services)
3. International border monuments (Indonesia/PNG border)
4. Critical infrastructure (airports, ports, highways, power, water, telco/data)
5. Mining operations (SML, mine grid origins including exploration grids)
6. Oil and gas operations (well locations, pipelines, production facilities)
7. Agriculture and Forestry (oil palm, plantations, forestry mapping)
8. Geohazard monitoring (volcanoes, active tectonic faults, landslides)
9. Sea level monitoring (vertical movement of NMSA tide gauges)
10. Rural cadastral control (customary land surveys)
11. Existing geodetic stations (for transformation parameter estimation)

PNG2020 data analysis

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1993-2025

HAUS GURIA
Rabaul Volcanological Observatory
LIVING MORE SAFELY WITH VOLCANOES

Steve Saunders
1998-2025

UNSW SYDNEY

Simon McClusky et al.
1990-1994

Data recovery and analysis of 33 years of GNSS/GPS static observation data archive (binary/RINEX) processed in a consistent ITRF2020 geodetic reference frame.

Station velocities estimated to 1 mmyr^{-1} at 95% CL
Positions estimated at 1 cm precision (95% CL) at ITRF2020 at epoch 2020.0 (1st January 2020)

SURVEYOR GENERAL PAPUA NEW GUINEA

Robert Rosa et al.,
1990-2025

Australian Government
Geoscience Australia

Australian National University
Research School of Earth Sciences
ANU College of Science

Paul Tregoning et al.,
1996-2008

Richard Stanaway
2000-2004

QUICKCLOSE

2005-2025

Rensselaer Polytechnic Institute 1824

Colleen Stevens
1993-1997

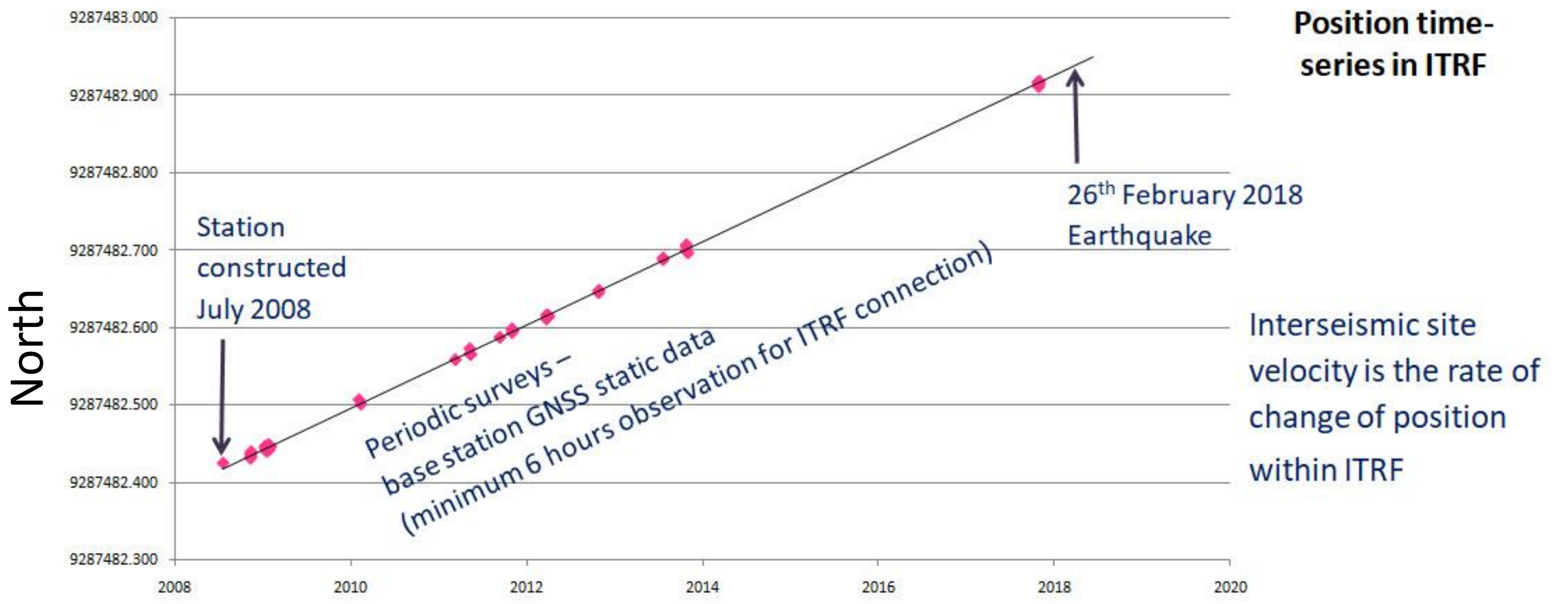
UC SANTA CRUZ

Laura Wallace et al.,
1997-2001

GNS SCIENCE
TE PŪ AO

2003-2013

interseismic velocity from campaign GNSS



Example – PSM 32567 (IAGI) Ridge Camp – topocentric North component

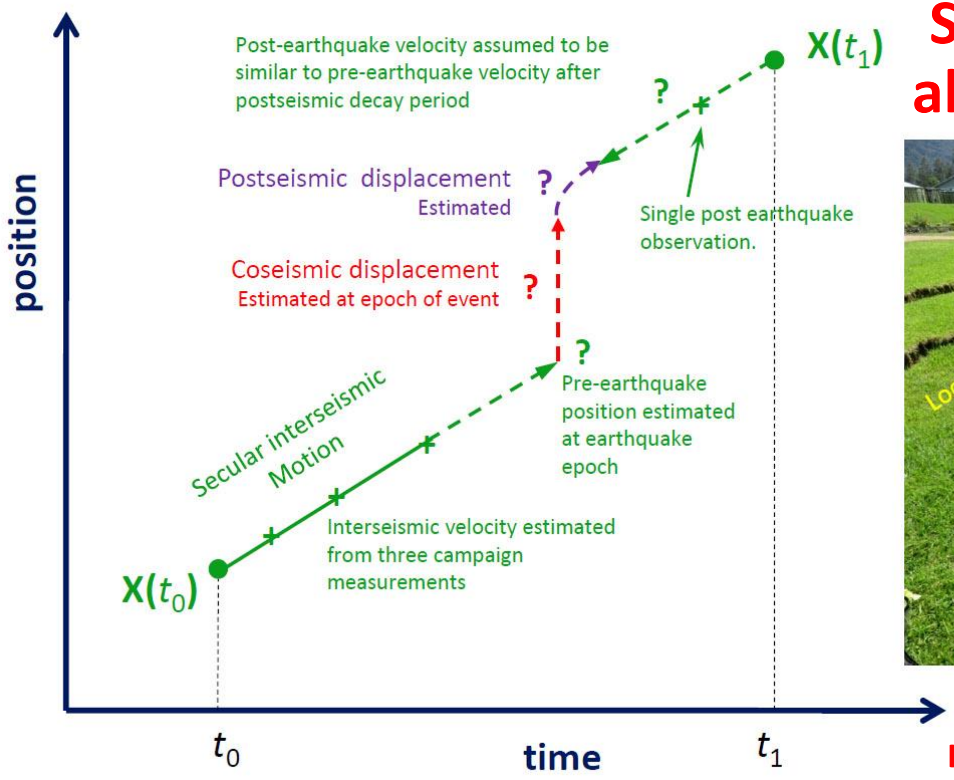
Interseismic motion is typically highly linear

GNSS Data analysis currently a weighted combination of AusPOS and NRCan-PPP

GINAN?

Effect of seismic displacements on site velocity estimation

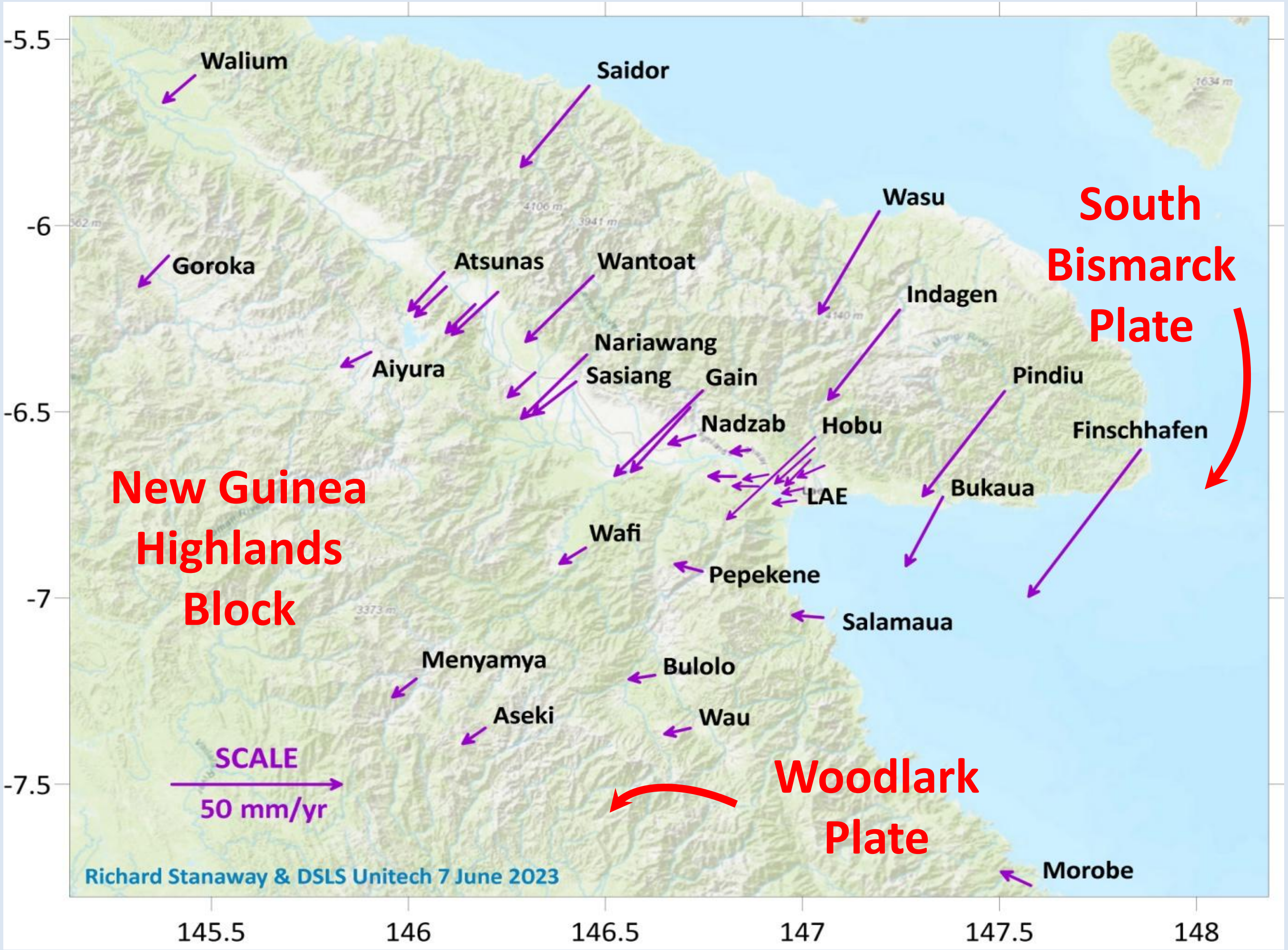
A major issue is the lack of CORS and campaign static data in seismically affected locations.
Many stations are also affected by localised deformation.
This impacts on the precision of site velocities and derived plate/microplate rotation parameters (Euler poles).
Sparse seismic network in PNG to constrain earthquake source locations.



Site stability is also a big issue!

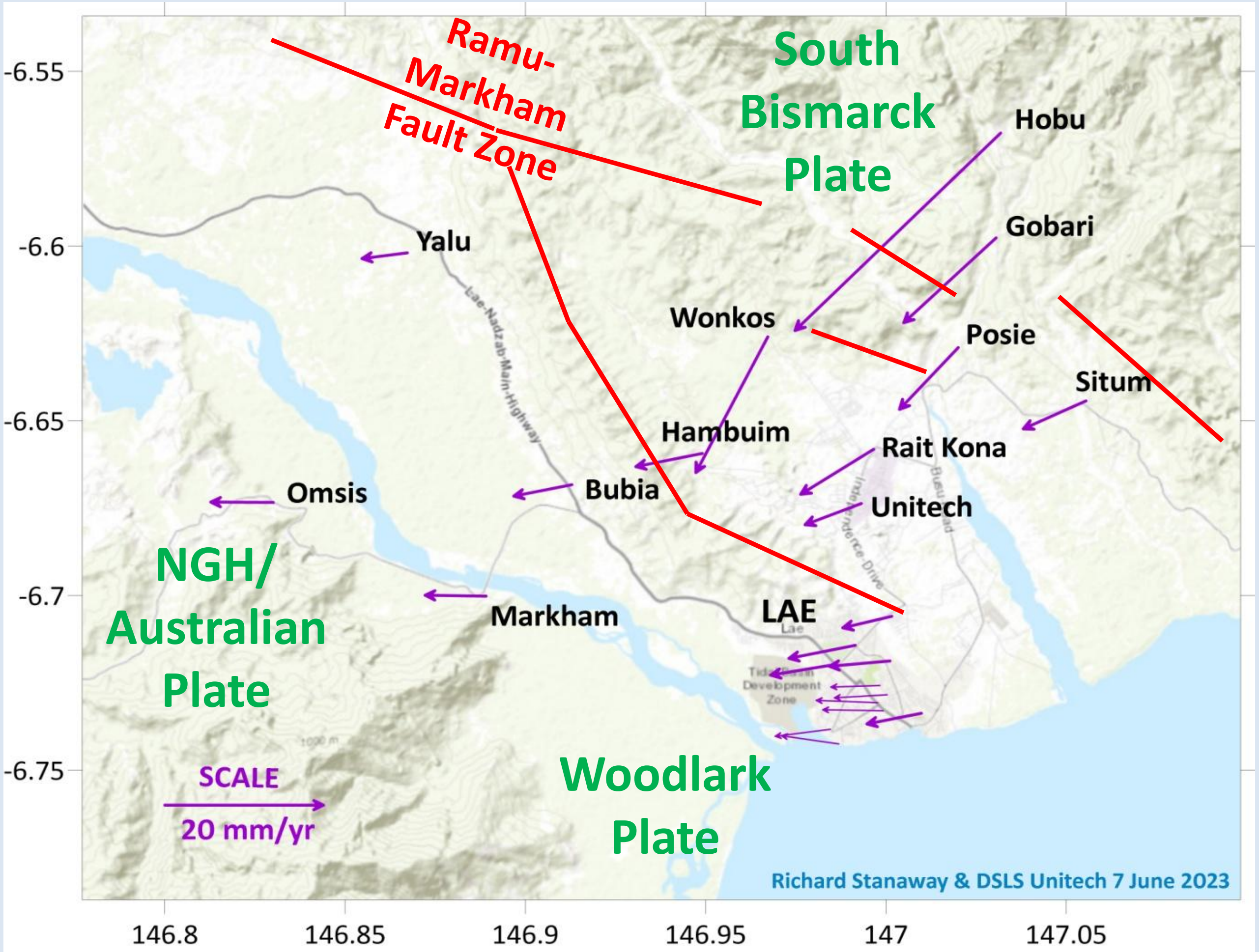
Good to have redundant local site ties / RMs!

RMFZ & LSZ velocities in a stable Australian Plate reference frame

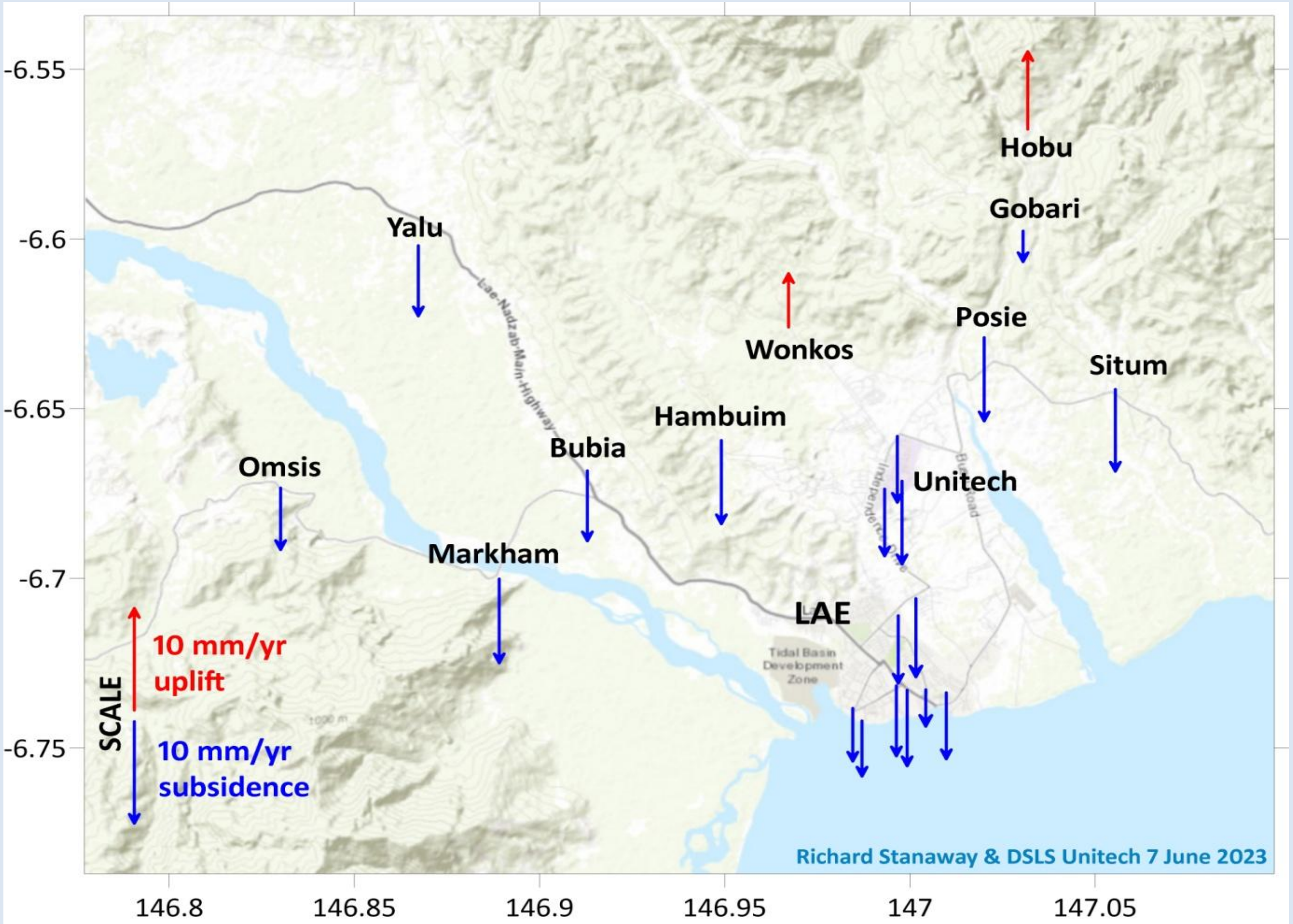


Lae Seismic Zone (LSZ) velocities in a stable Australian Plate reference frame

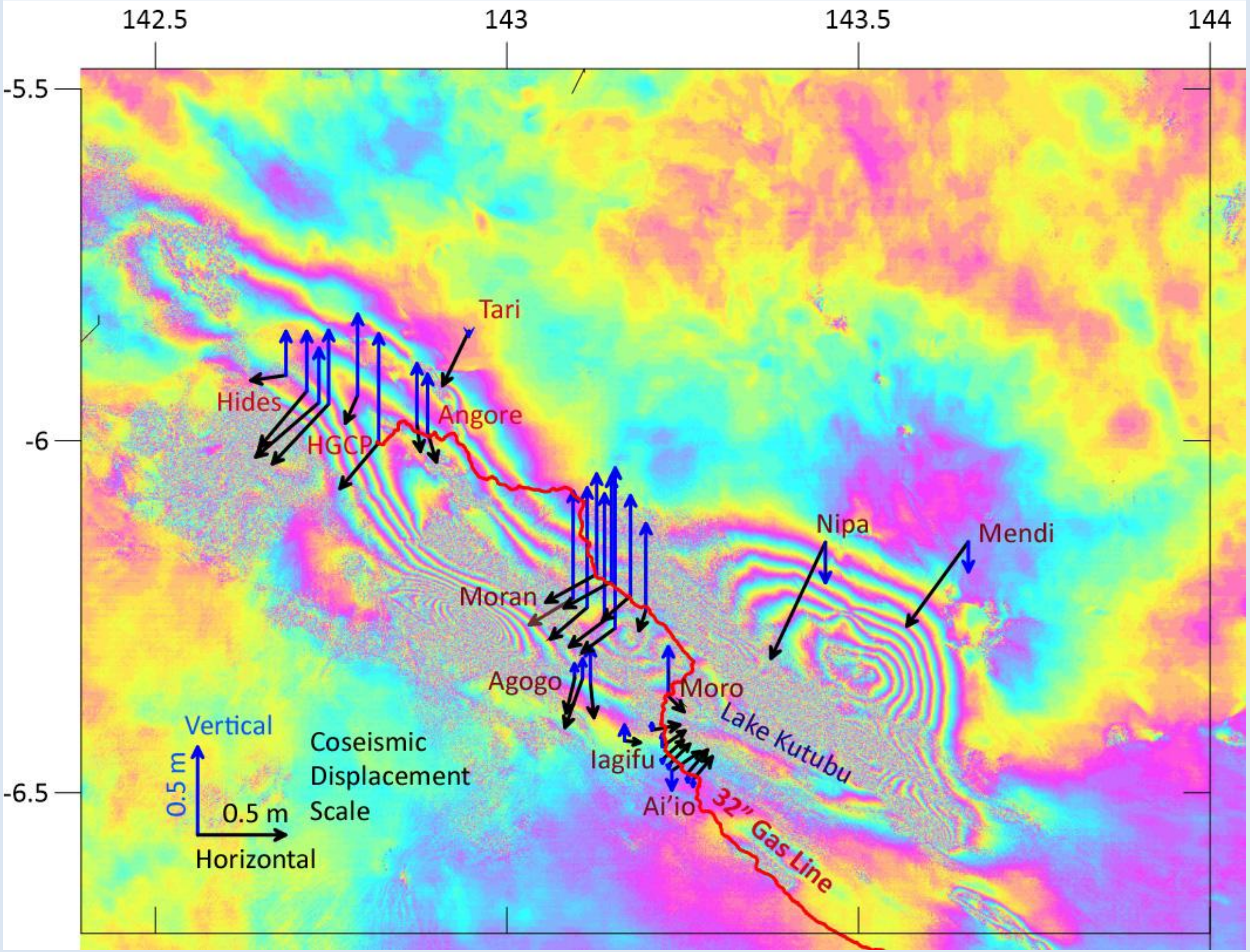
"Tectonics on steroids!"



Lae Urban area vertical velocities



Coseismic displacement from GNSS and remote sensing



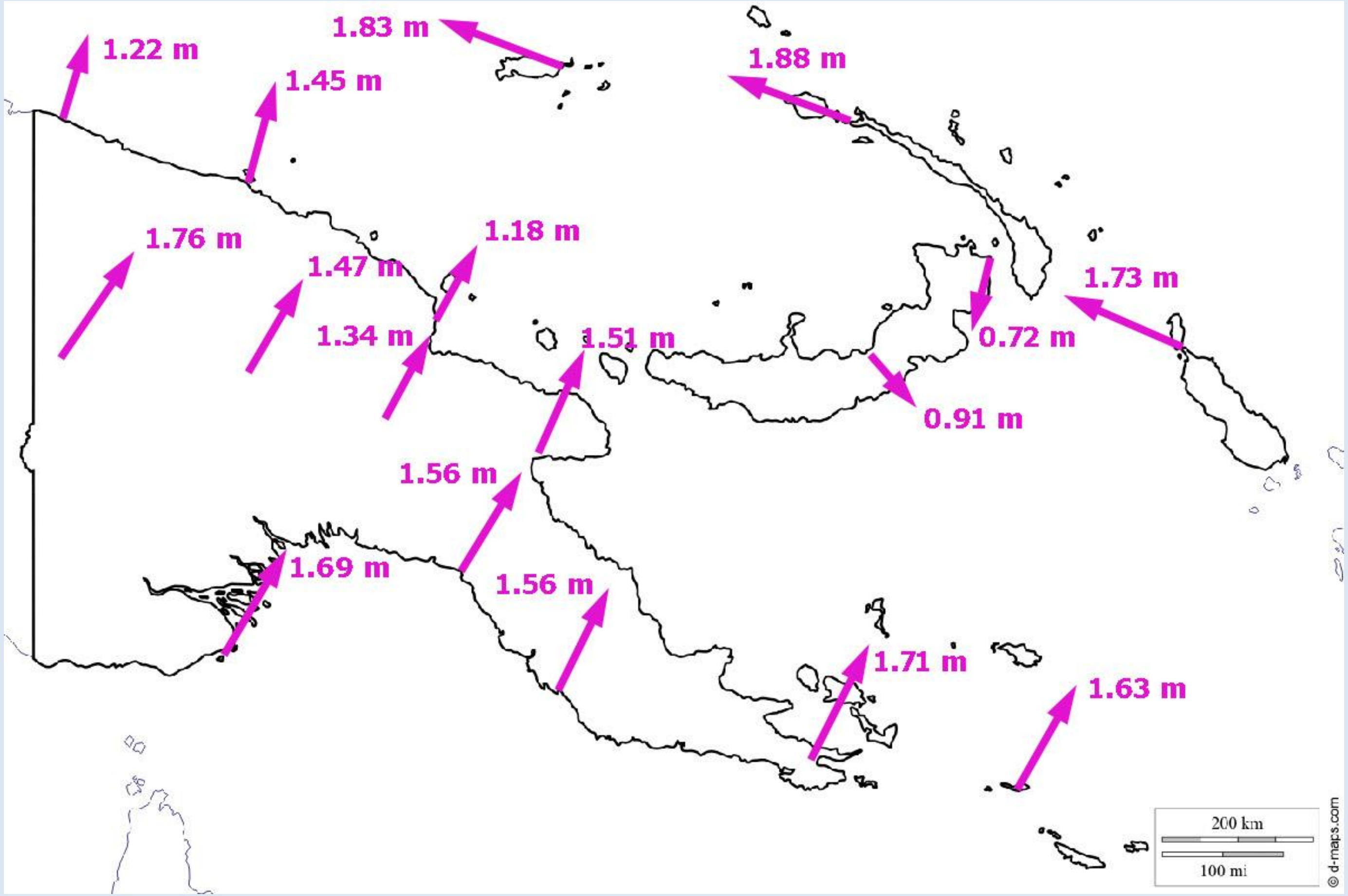
2018 PNG Highlands M_w 7.5 Earthquake sequence displacement observed by GNSS and Insar

(ALOS2 Interferogram, Jaxa,2018)

Spatial difference between PNG94 and PNG2020

The highly complex tectonic setting in PNG precludes the use of a conformal transformation (e.g. 7 parameter).

Grid transformation approach is essential (NTv2, GGXF/NetCDF, or GeoTIFF)



PNG geoid model

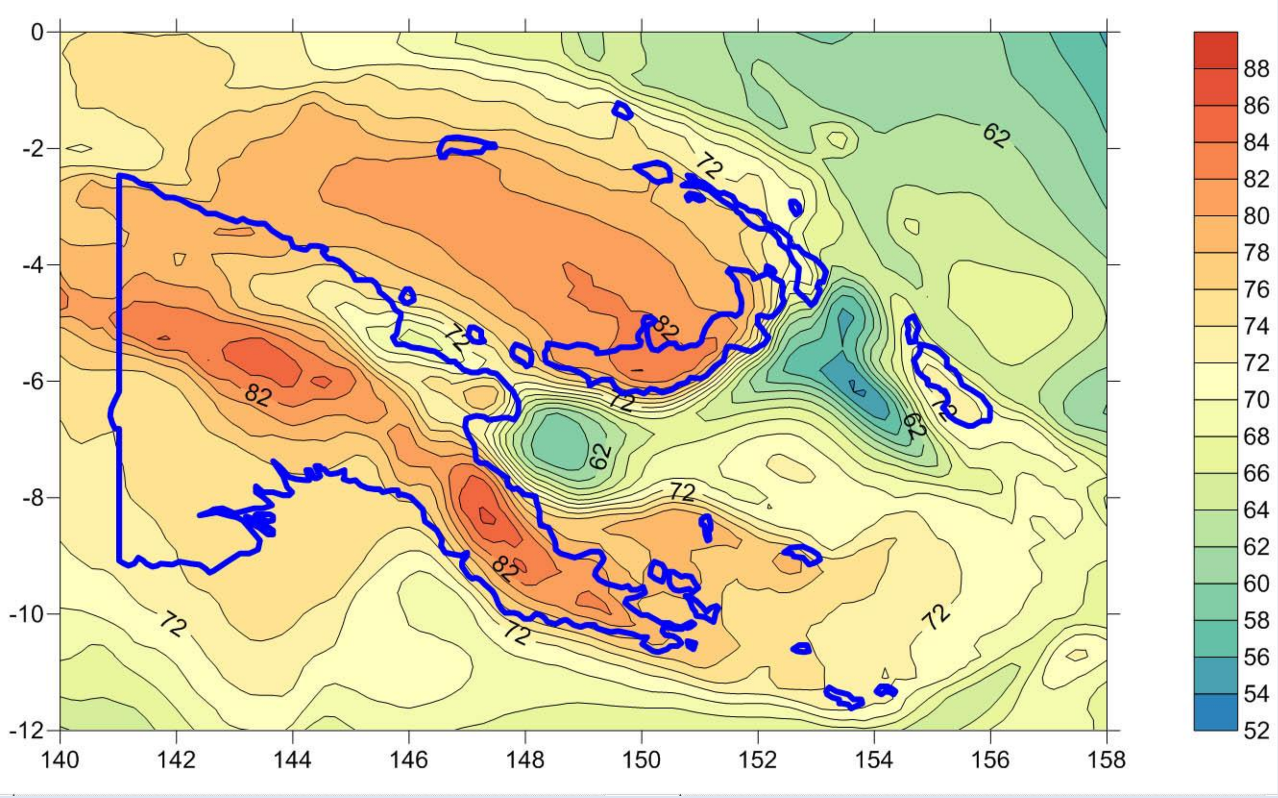
Currently EGM2008 corrected to fit observed MSL at several TG around PNG.

Precision 0.2 m at 1 σ.

Mean Dynamic Topography (MDT) of the sea surface is significant (between 0.8 and 1.4 m above EGM2008 geoid in PNG)

National airborne gravity survey and NMSA TG analysis required to improve PNG geoid

Dual gravimetric and MSL aligned geoid is required for practical surveying applications with HAT/LAT offset models for hydrographic surveys.



PNG08 geoid model, Stanaway, 2011

PNG2020 Datum components

Physical Monuments – PSMs (passive ground marks), CORS antenna mounts

Legal – Geodetic Registry (EPSG/ISO) - GIS, PNG Government Gazette

Information – geodetic database (Coordinates, elevations, metadata), PSM sketches, kml files etc. – **UN-FAIR Principle** – open and free online access

Access – CORS data portal, RTCM/NTRIP streams, online access to database (Potential AusPOS update to support PNG2020/PNG94 and MSL PNG08)

Models –velocity grids, transformation tools & geoid models - GUI projected CRS (UTM based PNGMG2020 grid and local TM town/project grids)

Knowledge – stakeholder involvement and training, guidelines (DLPP, MRA, DPE, NAC, Urban Authorities, utilities)

Adopt ICSM (Australia & NZ) and LINZ (NZ) formats and guidelines?

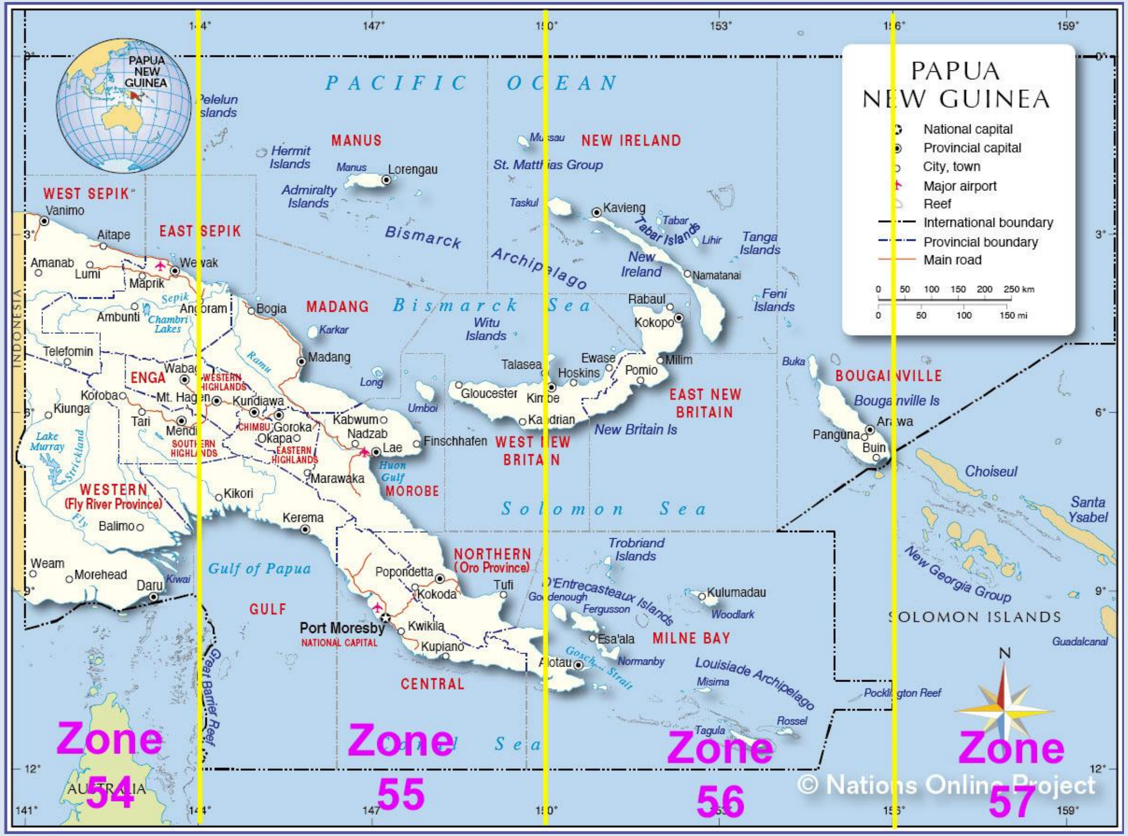
PNG2020 Projected CRS

Mapping grids

PNGMG2020 based on UTM

same as with PNG94 (PNGMG94) and AGD66 (AMG66)

Zones 54 to 58



PNG2020 Projected CRS Grids

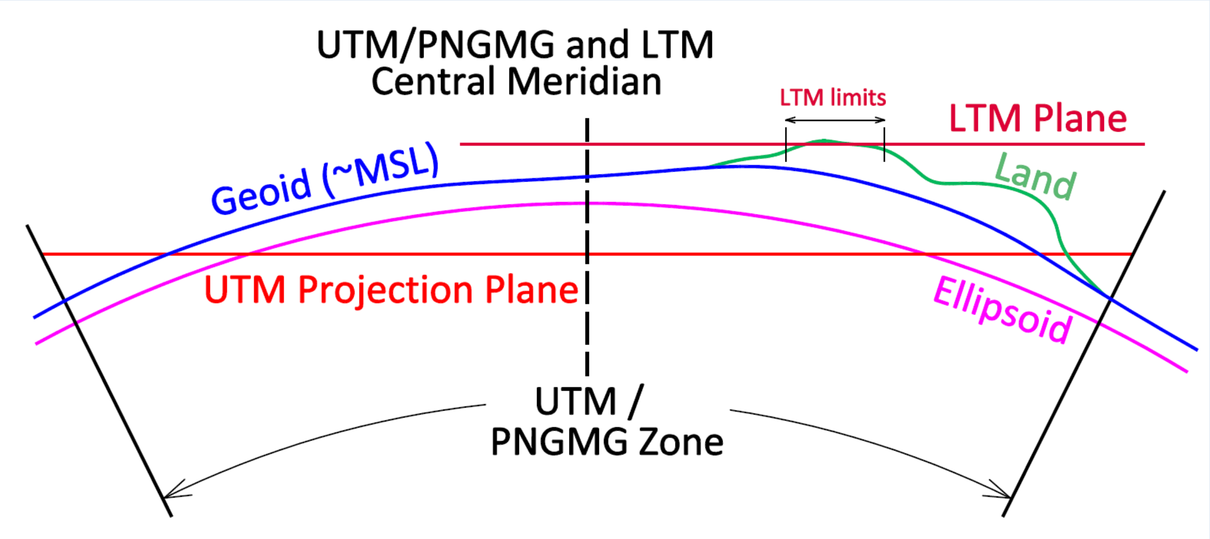
Town grids

Local Transverse Mercator (LTM) projections with SF close to 1.000000 for use with cadastral and engineering surveys

Same latitude/longitude (PNG2020) as PNGMG2020

Bearing equality with PNGMG2020 (no rotation)

POM2020 – NCD
LAE2020 – Lae
HGN2020 – Mt Hagen
WWK2020 - Wewak
RAB2020 – Rabaul
and all major towns



Town Grid LTM formulation

$$\lambda_{0(\mathrm{LTM})} = \lambda_{0(\mathrm{PNGMG2020})}$$

LTM Central meridian is same as PNGMG2020

$$\phi_{0(\mathrm{LTM})} = \phi_{0(\mathrm{PNGMG2020})} = 0^{\circ}$$

LTM latitude origin is same as PNGMG2020

$$E_{0(\mathrm{LTM})} = E_{LO} + \frac{500000 - E_{UO}}{C}$$

False Easting of LTM CM

$$N_{0(\mathrm{LTM})} = N_{LO} + \frac{10000000 - N_{UO}}{C}$$

False Northing of LTM latitude origin

$$k_{0(\mathrm{LTM})} = \frac{0.9996}{C}$$

LTM CM scale factor

E_{UO}, N_{UO} PNGMG coordinates of local origin

E_{LO}, N_{LO} LTM coordinates of local origin

$$C \approx \frac{\left(0.9996 + \left(E_{\mathrm{PNGMG2020}} - 500000\right)^{2} \cdot 1\mathrm{E}^{-14} \cdot 1.2379\right) \cdot 6357000}{6357000 + h}$$

PNGMG2020 combined scale factor (simplified formula)

PNG2020 – Geodetic Registry

EPSG geodetic registry (and ISO TC 211 registry)
This is an industry standard for GIS/Mapping and positioning software

EPSG codes for the PNG2020 datum, projected map grids (PNGMG2020 Zone 54 to Zone 58 and LTM based town grids)

Kinematic tectonic model (velocity grid) – to transform between ITRF2020 (dynamic coordinates) and PNG2020 (NTv2 & GGXF format)

PNG94(2022) to PNG2020 transformation grid (NTv2 & GGXF)

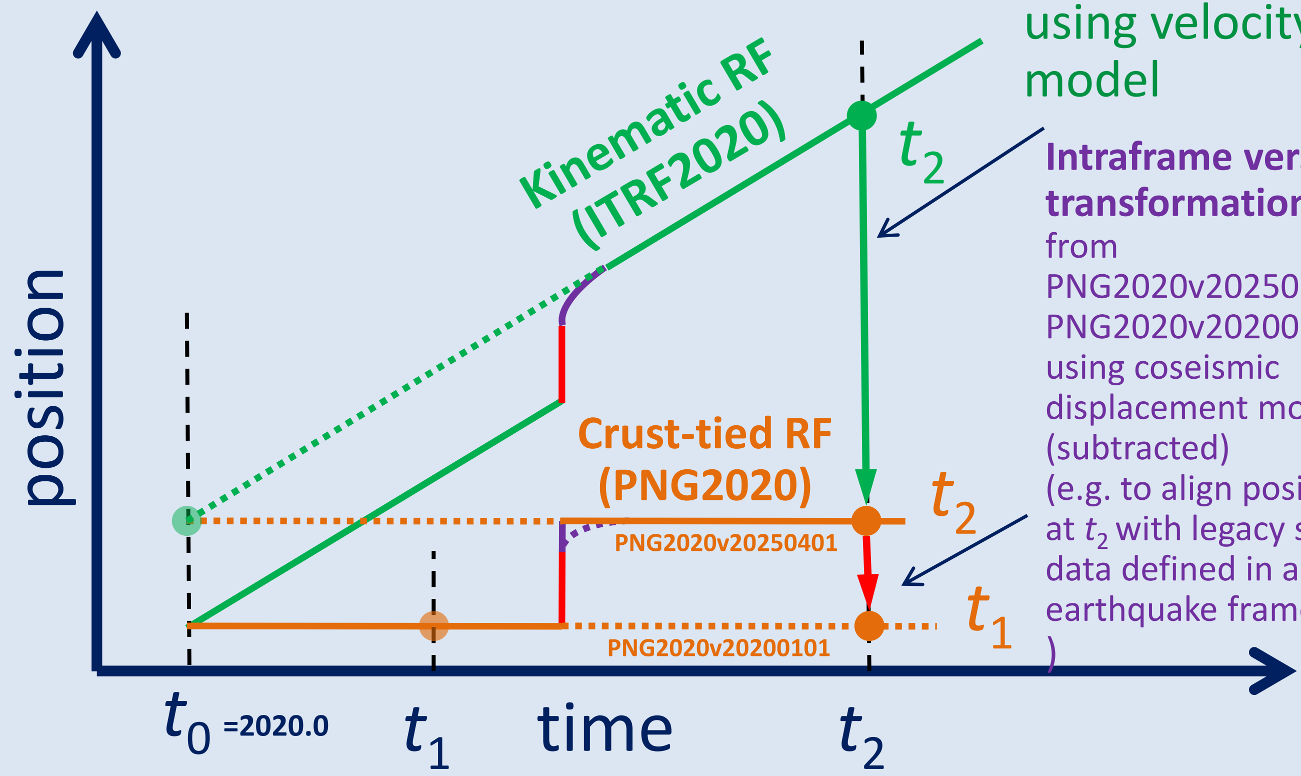
AGD66 to PNG2020 transformation grid (NTv2 & GGXF)

Coseismic displacement grids (as required – NTv2 & GGXF)

PNG2020 dual frame how will it work?

Strictly speaking, PNG2020 is not really a datum but a system since coordinates of “fixed points” at the reference epoch change as result of seismic displacements and geodetic adjustments!

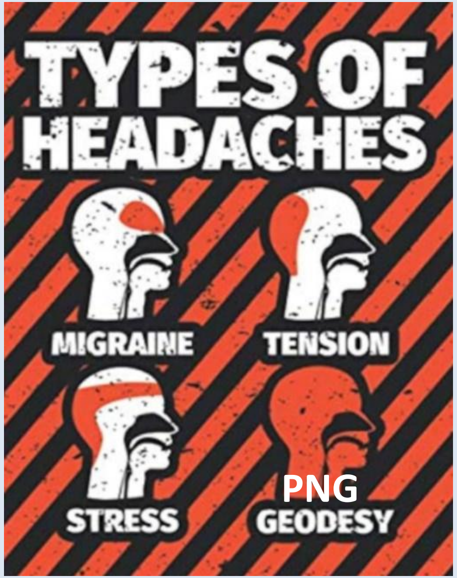
Trajectory estimated from interpolation of velocity, coseismic and other displacement grids



Intraframe propagation
from t_2 to t_0 using velocity model

Intraframe version transformation
from PNG2020v20250701 to PNG2020v20200101 using coseismic displacement model (subtracted) (e.g. to align position at t_2 with legacy spatial data defined in a pre-earthquake frame at t_1)

PNG2020 current progress



OSG Geodetic Section will progressively complete remaining observations around key geodetic stations in PNG over the next 3 months

Currently 80% of primary geodetic stations have been reobserved to date to define PNG2020 fiducial network for government gazettal.

Gazettal of PNG2020 by 50th Anniversary of Independence (16 September 2025)

Thank you!