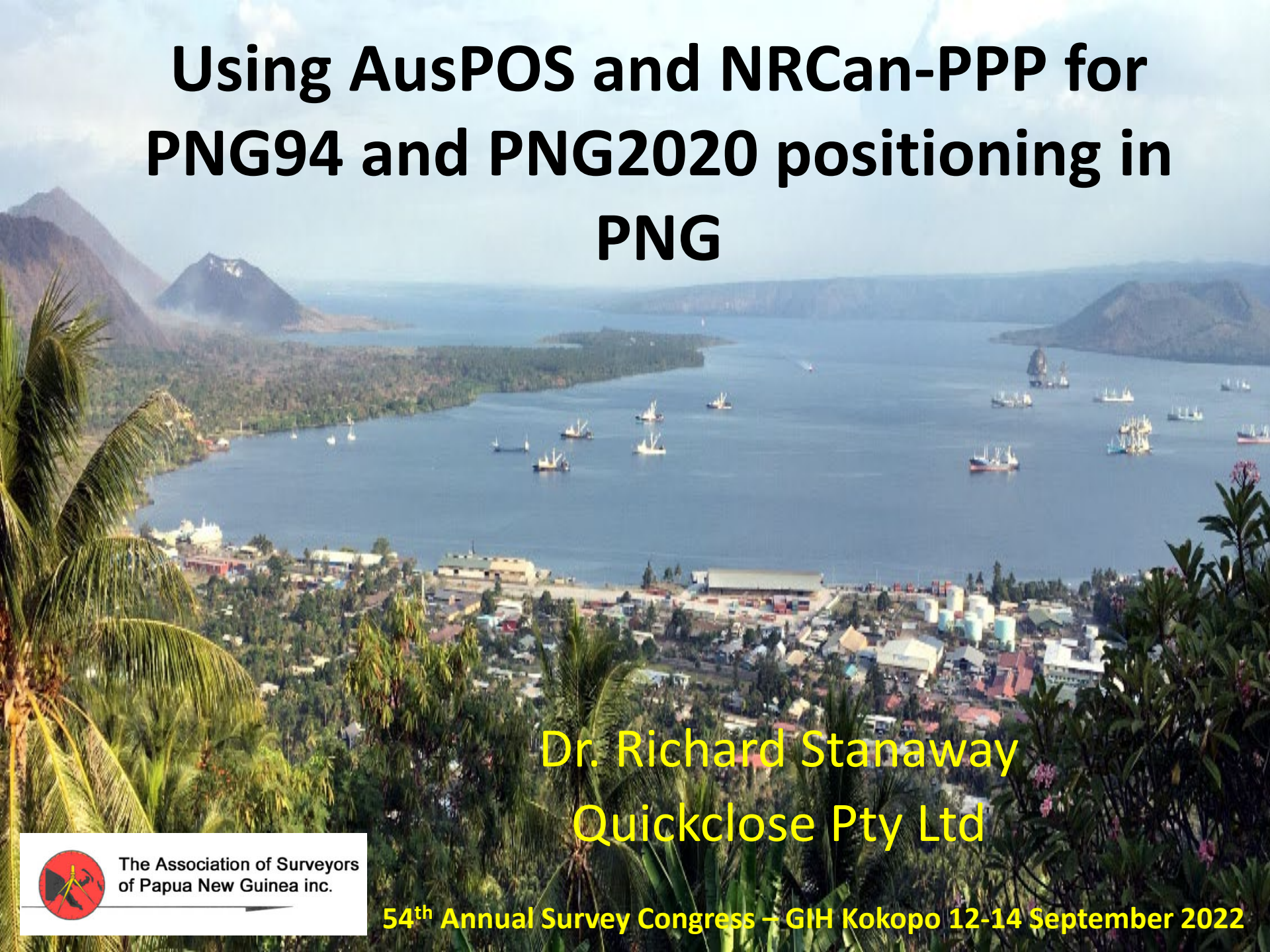
Using AusPOS and NRCan-PPP for PNG94 and PNG2020 positioning in PNG



Dr. Richard Stanaway
Quickclose Pty Ltd

The Association of Surveyors of Papua New Guinea inc.

54th Annual Survey Congress – GIH Kokopo 12-14 September 2022

What is GNSS PPP?

GNSS is **Global Navigation Satellite Systems**

(GPS Glonass Galileo Beidou QZSS SBAS-SouthPAN)

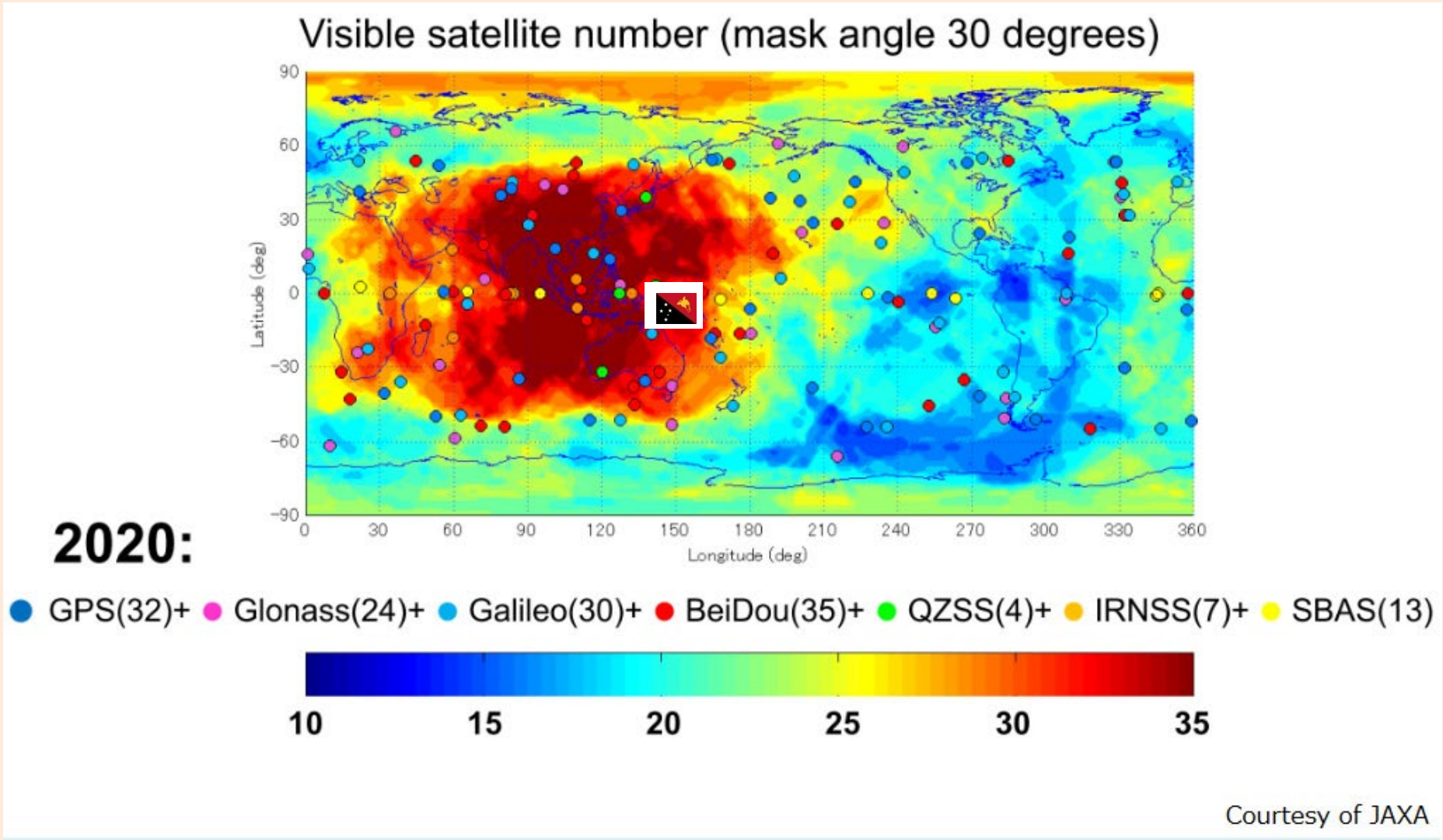
PPP is **Precise Point Positioning**

Uses precise GNSS orbit models and clock corrections to improve GNSS positioning accuracy from 2-5 m (standard positioning) to 5 mm (8+ hour dual-frequency static occupation)

PPP does not need a local or regional reference (base) station and is solely based on precise orbit models.

PPP coordinates are related to the IGS14 reference frame (GPS realisation of ITRF2014) and are NOT localised to national datums such as PNG94 unless a transformation is applied. Difference can be 2.5 m

PNG is in the GNSS “Hotspot”



JAXA, Yoshikatsu Iotake, 2018

AusPOS

AusPOS is a free online GPS processing service provided by Geoscience Australia (GA)

AusPOS uses precise GPS orbit models and nearby regional CORS to compute baseline vectors between the stations to 5 mm precision (8+ hour dual-frequency static occupation)

Similar free services are provided by the US Govt. (OPUS)

NRCan-PPP

NRCan (Natural Resources Canada) provides a free online GPS+Glonass PPP processing service which is very fast.

NRCan-PPP uses precise GPS and Glonass orbit models and can provide up to 5 mm precision (8+ hour dual-frequency static occupation). Also kinematic (post-processed) processing.

NRCan-PPP and AusPOS positions are dynamic

NRCan-PPP and AusPOS provide ITRF2014/IGS14 coordinates at the epoch of observation. AusPOS positions in PNG are related to ITRF2014 North of 8 degrees S. Positions S of 8 degrees are also incorrectly provided in Australian datums (GDA2020 and GDA94)

These coordinates will change for “fixed” points in PNG by up to 9 cm a year due to plate tectonics.

The coordinates WILL be different from PNG94 (by up to 2.5+ metres) and the proposed PNG2020 by up to 25 cm (now)

A time-dependent transformation MUST be applied to the ITRF coordinates to estimate PNG94 or PNG2020

Example of ITRF coordinate changes

ITRF (ITRF2014, ITRF2020 etc.) is considered to be coincident with WGS 84 for most practical purposes

5.3 UTM Grid, GRS80 Ellipsoid, ITRF2014

Station	East (m)	North (m)	Zone	Ellipsoidal Height (m)
WAIG	519913.344	8956199.652	55	154.650

WAIG in 2014

5.3 UTM Grid, GRS80 Ellipsoid, ITRF2014

Station	East (m)	North (m)	Zone	Ellipsoidal Height (m)
WAIG	519913.635	8956200.130	55	154.660

WAIG in 2022

Diff. E 0.29 m N 0.48 m in 8.5 years!

Change is due to plate movement

What is required to obtain PNG94 or PNG2020 using PPP or AusPOS?

Hardware:

Dual-frequency geodetic GNSS/GPS receiver.

Sky visibility:

As much sky visibility as possible to improve the number of satellites observed, improve the solution geometry and to remove local multipath and signal diffraction

Time:

Observe for as long as practicable. 6 hours is the minimum to obtain reliable centimetre accurate positions.

File format:

GNSS Observation file is required in RINEX format (check software)

GNSS Configuration required

The minimum requirements are to log:

C1 Pseudorange on L1 frequency band
C2/P2 Pseudorange on L2 frequency band
L1 carrier-phase on L1 frequency band
L2 carrier-phase on L2 frequency band

Recording (epoch) interval

30 seconds for standalone long-static observations
(this is the epoch interval used by AusPOS and NRCan)
10 seconds for normal static surveys
1 second for active Lidar/drone base stations

If possible turn off “start new file each day” for normal static.
Otherwise at 10:00 am PNG time your receiver starts a new file.

Important checks for your equipment (especially first time use)

Check the tribrachs with a rotation test or plumbob check. If necessary adjust the optical plummet and level bubble.

Use wooden or fibre-glass tripods as aluminium tripods deform with temperature differences.

Do a test observation and AusPOS/NRCan before going into the field to ensure everything works.

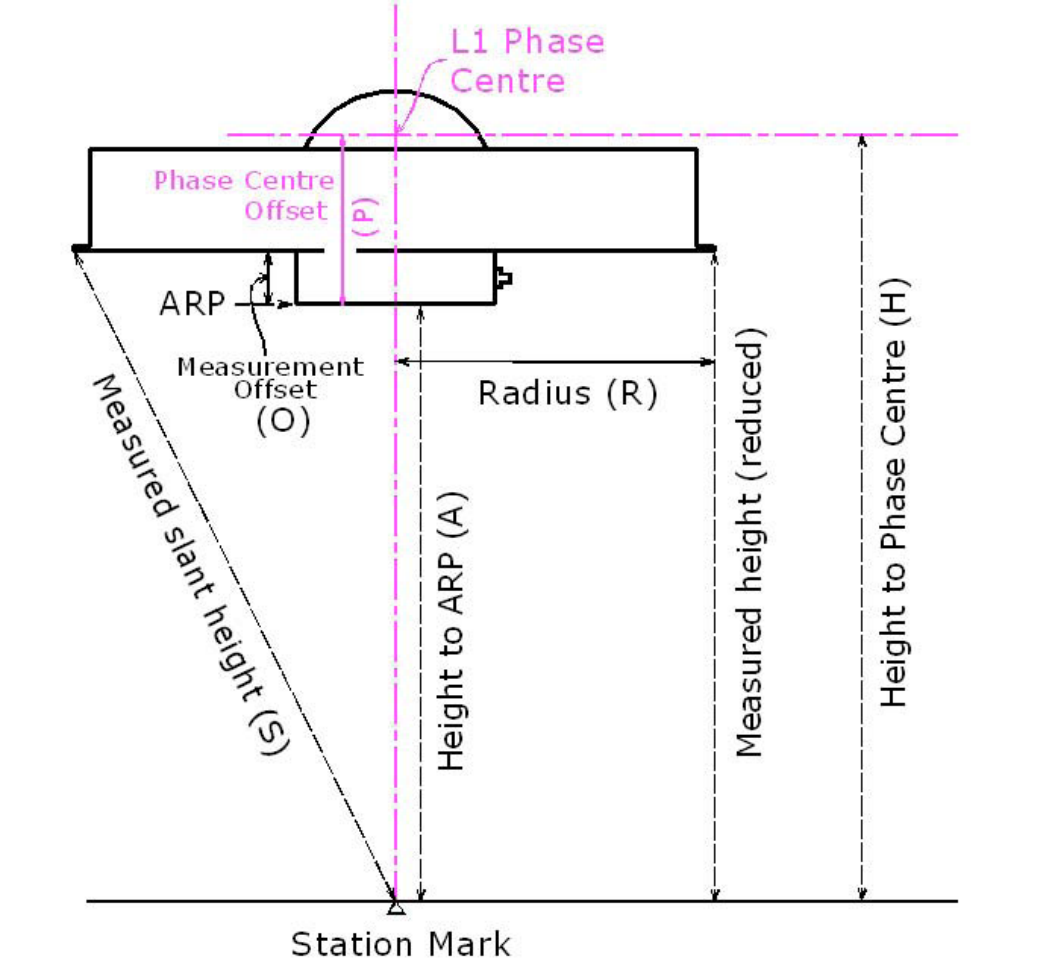
Antenna Height measurement

It is the BIGGEST source of heighting errors in GNSS surveys!

AusPOS and NRCan require **Antenna Reference Point** (ARP) heights.

Entering the measurement slant height can result in

20 cm + height errors!



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Antenna Reference Point (ARP)

The ARP Height is usually the lowest point or surface of a GNSS Antenna. This is different from the Antenna Phase Centre (APC) height where GNSS measurements are made to.

Entering the APC height can also result in 20 cm + height errors

COMNAV

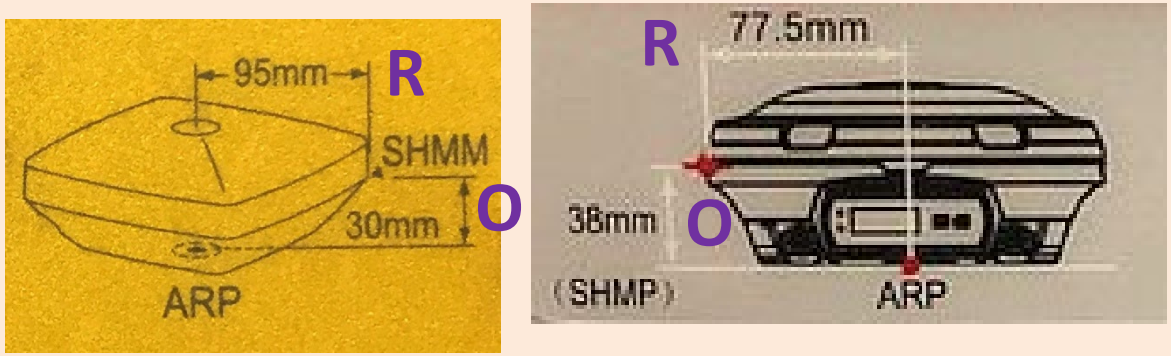
Leica GS15

Topcon Hiper-SR

Converting slant heights to ARP heights

Three antenna dimensions are required:

1. Slant height measurement (S or SHM)
2. Radius (R) from the measurement point to the antenna centre
3. Vertical offset (O) from the measurement point to the ARP



You can take these measurements yourself if you can't find them

Also visit https://geodesy.noaa.gov/ANTCAL/ to view models of nearly all GNSS antennas in production

$$ARP = \sqrt{(S^2-R^2)} - O$$

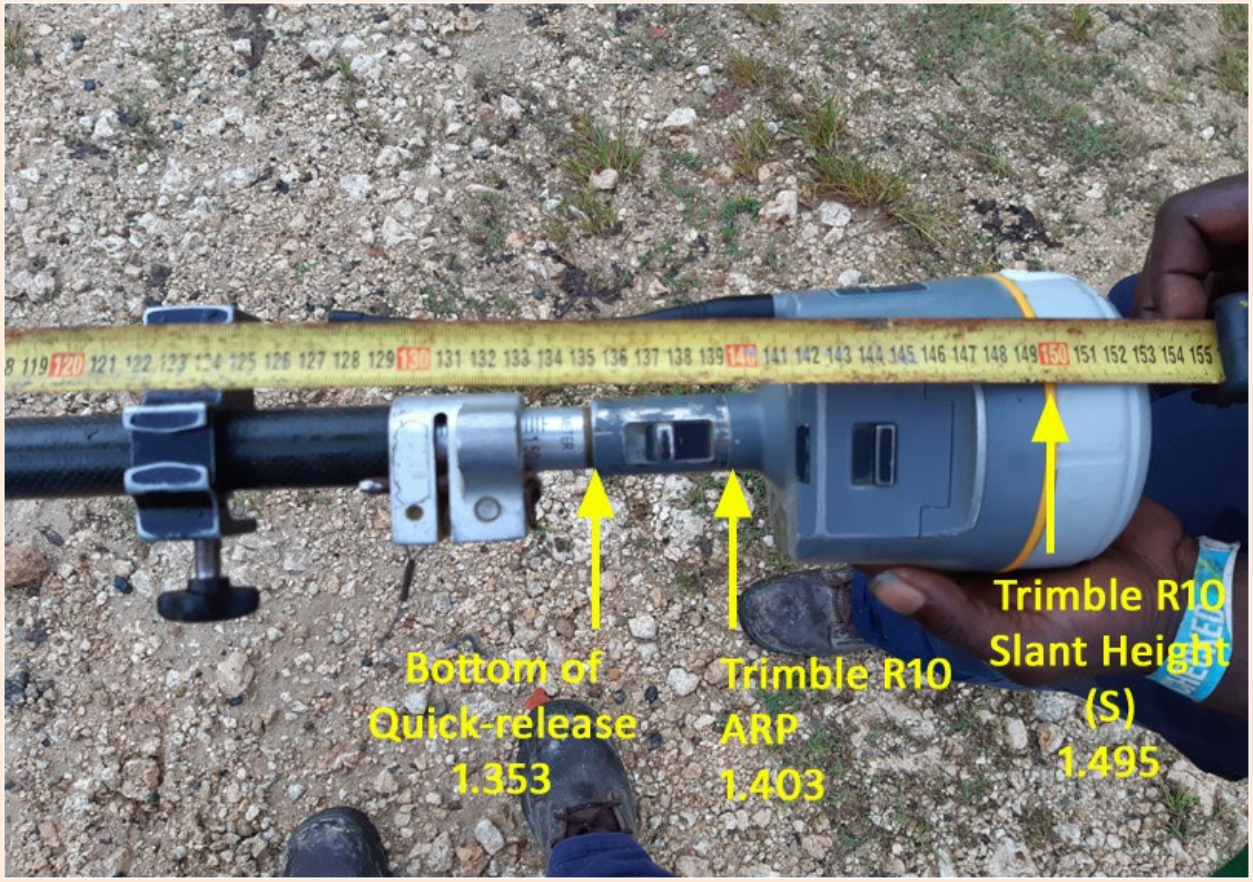
Direct measurement of ARP

Some equipment allows direct ARP height measurment.

e.g. An antenna on a pole (pogo/pokko stick)

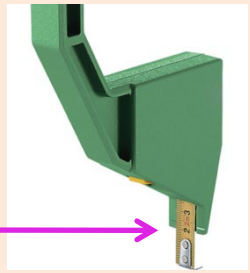
Be careful of things like Quick-release adapters

or using the measurements provided on extendable poles



Leica measuring hooks

Leica have provided measuring hooks that measure an offset below the antenna.



ARP = hook ht + 0.36 (tripod long)

ARP = hook ht + 0.255 (tripod short)

The 360 mm offset is written on the g-hook and is meant for the long tripod!

Observing time and conditions

As long as possible to get the highest precision.

Typically 6 hours of observations approaches final precision with 5 mm uncertainty.

Less than 6 hours, the precision degrades to 5 cm for a 1 hour observation.

This is dependent on good sky visibility and good satellite geometry

If there are trees and buildings near or over the antenna, the precision can degrade by a factor of 3 and longer observation is required. A useful solution is not guaranteed!

Rinex file format and edits

The receiver observation file is required to be logged as a RINEX file or if RINEX logging not possible, the raw data file needs to be converted to RINEX format for submission to NRCan-PPP and AusPOS

It is possible to edit RINEX files using a text editor (Notepad etc.) to ensure that the antenna model and ARP height are correct.

NRCan-PPP assumes RINEX file header has correct antenna model and ARP height otherwise a Null antenna and default ARP height are used. This can result in large height errors.

AusPOS allows for user selection of Antenna Model and ARP height

Editing a RINEX file

Great care is needed to edit RINEX files.

No TAB spacing is allowed and critical data needs to be exactly in the right column of the file otherwise the file is rendered invalid.

The Antenna model (NGS format) needs to be entered between columns 21 and 40.

The ARP height needs to be entered between columns 9 and 14 with the decimal point at column 7

RINEX file format (v 2)

Antenna Model

ARP Height

WAIG0010.20o - Notepad

File Edit Format View Help

```
     2.11           OBSERVATION DATA    M                   RINEX VERSION / TYPE
GRX1200 V8,70                           2020 01 02 09:59    PGM / RUN BY / DATE
WAIG PSM 33362 DOMES 51007M001                              MARKER NAME
WAIG                                                        MARKER NUMBER
                                                            OBSERVER / AGENCY
496699              LEICA GRX1200+GNSS  8.70/6.112          REC # / TYPE / VERS
13286-034           LEIAR10             NONE                ANT # / TYPE
 -5288102.4338  3410380.7303 -1039518.3794                  APPROX POSITION XYZ
        0.0940        0.0000        0.0000                  ANTENNA: DELTA H/E/N
     1     1                                                WAVELENGTH FACT L1/2
    13    C1    L1    D1    S1    P2    L2    D2    S2    C2# / TYPES OF OBSERV
          C5    L5    D5    S5                              # / TYPES OF OBSERV
                                                            COMMENT
    30.000                                                  INTERVAL
  2020    01    01    00    00    0.0000000     GPS         TIME OF FIRST OBS
  2020    01    01    23    59   30.0000000     GPS         TIME OF LAST OBS
    18                                                      LEAP SECONDS
BIT 2 OF LLI FLAGS DATA COLLECTED UNDER A/S CONDITION       COMMENT
SNR is mapped to RINEX snr flag value [2-9]                 COMMENT
LX:     = 25dBHz -> 1; 26-27dBHz -> 2; 28-31dBHz -> 3       COMMENT
       32-35dBHz -> 4; 36-38dBHz -> 5; 39-41dBHz -> 6       COMMENT
       42-44dBHz -> 7; 45-48dBHz -> 8; >= 49dBHz -> 9       COMMENT
                                                            END OF HEADER
 20 01 01 00 00  0.0000000  0 17G02G05G06G12G13G15G19G24G28G30R01R10
                               R11R12R13R22R23
  20113652.320   105697951.178 9       247.834          49.250    20113643.640
  82362014.45248       193.117          48.950

  23224168.700   122043807.960 8      1941.079          46.100    23224163.580
  95099073.22846      1512.530          41.850    23224164.340

  21778507.920   114446826.554 8     -2448.312          45.250    21778505.060
  89179329.79047     -1907.776          44.150    21778506.000    21778507.860
```

RINEX file format (v 3)

Antenna Model

ARP Height

LAE200PNG_R_20222500551_01D_30S_MO.rnx - Notepad

File Edit Format View Help

```
     3.02           OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
SC400A              PNG University of Te20220908 000745 UTC PGM / RUN BY / DATE
       G = GPS       R = GLONASS       C = COMPASS          COMMENT
       S = SBAS      J = QZSS          E = GALILEO          COMMENT
LAE2_DOMES_51002                                           MARKER NAME
                                                           MARKER NUMBER
GEODETIC                                                   MARKER TYPE
Mr Jerry Paraka     PNG University of Te                   OBSERVER / AGENCY
SC4003A2100030      SC400A              2.12-211105-STX    REC # / TYPE / VERS
S21110033           STXSA1200       STXR                   ANT # / TYPE
  4416011.4700   713873.4343  4531461.3374                  APPROX POSITION XYZ
        0.0830        0.0000        0.0000                  ANTENNA: DELTA H/E/N
G   16 C1C L1C D1C S1C C2Y L2Y D2Y S2Y C2X L2X D2X S2X C5Q  SYS / # / OBS TYPES
       L5Q D5Q S5Q                                         SYS / # / OBS TYPES
R   12 C1P L1P D1P S1P C2P L2P D2P S2P C2C L2C D2C S2C      SYS / # / OBS TYPES
C    8 C1I L1I D1I S1I C6I L6I D6I S6I                     SYS / # / OBS TYPES
S    4 C1C L1C D1C S1C                                     SYS / # / OBS TYPES
J   12 C1C L1C D1C S1C C2X L2X D2X S2X C5Q L5Q D5Q S5Q      SYS / # / OBS TYPES
E   12 C1C L1C D1C S1C C5Q L5Q D5Q S5Q C6C L6C D6C S6C      SYS / # / OBS TYPES
DBHZ                                                       SIGNAL STRENGTH UNIT
    30.000                                                 INTERVAL
  2022    09    07    05    51     0.0000000     GPS       TIME OF FIRST OBS
  2022    09    07    23    59    30.0000000     GPS       TIME OF LAST OBS
     0                                                     RCV CLOCK OFFS APPL
G L1C  0.00000                                             SYS / PHASE SHIFT
```

Submission to NRCan-PPP

Requires an account (log in) and is free.

Best to wait 1-2 days after observation to utilise IGS rapid precise orbits (2-3 weeks for final precise orbits)

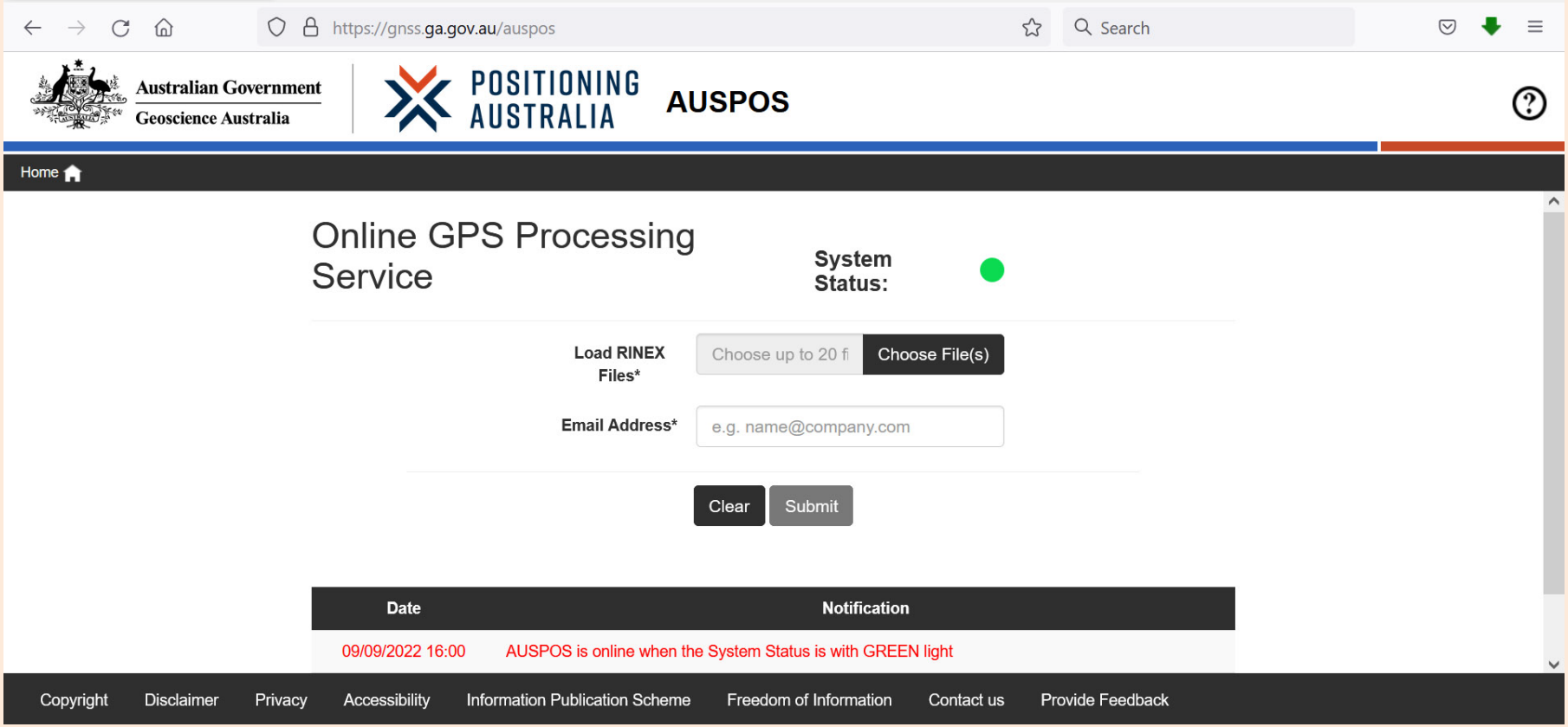
Rinex files can be zipped to speed up upload.

https://webapp.csrs-scrs.nrcan-rncan.gc.ca/geod/tools-outils/ppp.php?locale=en

Log in to the service

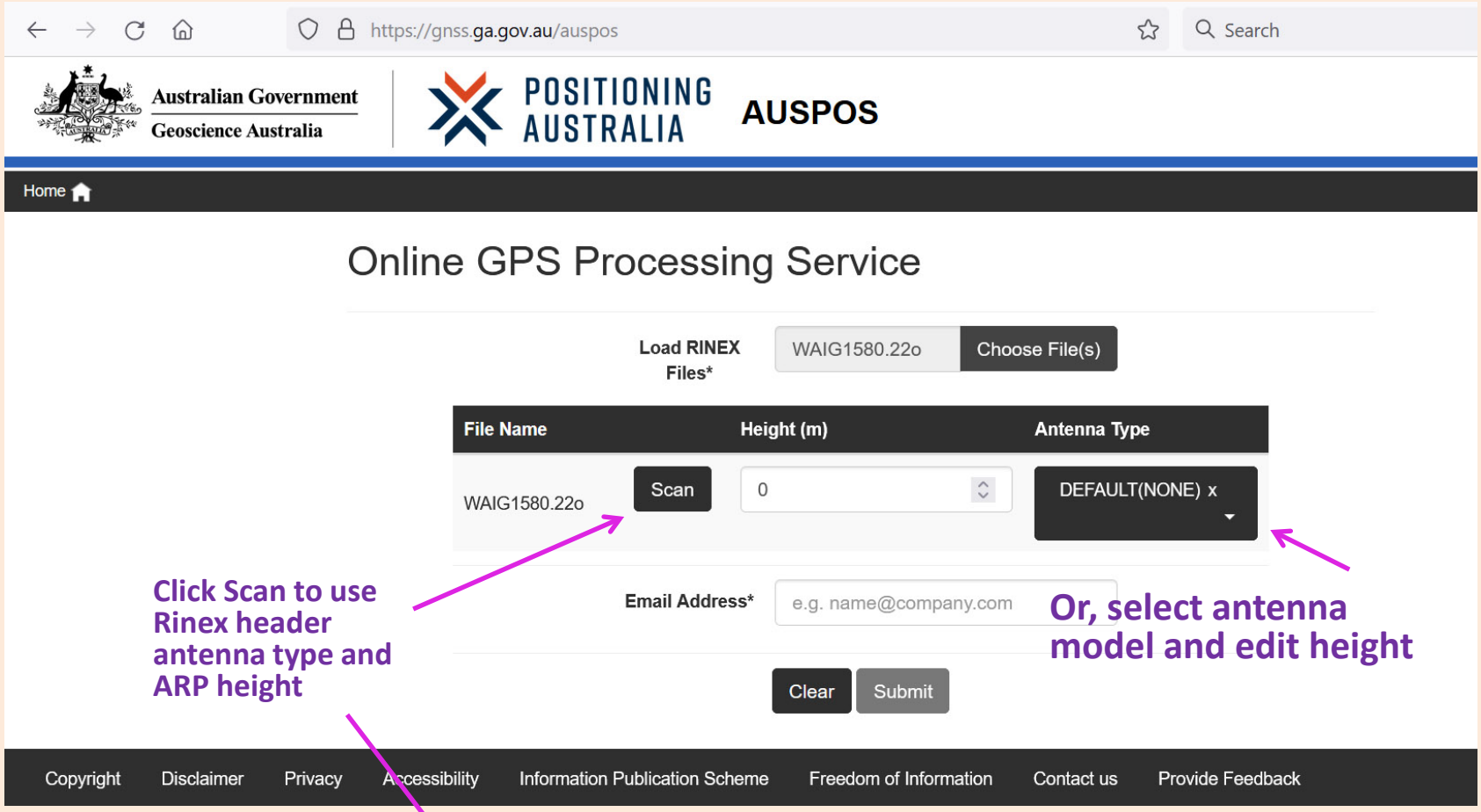
Select ITRF
Select Static
Select file to Upload
SUBMIT

Submission to AusPOS



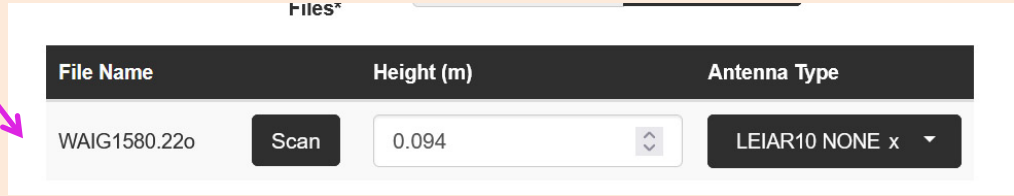
Best to wait 1-2 days after observation to utilise IGS rapid precise orbits (2-3 weeks for final precise orbits)

Submission to AusPOS



Click Scan to use Rinex header antenna type and ARP height

Or, select antenna model and edit height



NRCan-PPP report (1)

CSRS-PPP 3.50.3 (2022-03-04)

WAIG1570.22o
WAIG PSM 33362 DOMES 51007M001

Data Start	Data End	Duration of Observations
2022-06-06 00:00:00.00	2022-06-06 23:59:30.00	23:59:30
Processing Time		**Product Type**
00:37:04 UTC 2022/07/06		NRCan/IGS Final
Observations	**Frequency**	**Mode**
Phase and Code	Double	Static

Elevation Cut-Off	Rejected Epochs	Fixed Ambiguities	Estimation Steps
7.5 degrees	0.00 %	87.99 %	30.00 sec

Antenna Model	APC to ARP	ARP to Marker
LEIAR10 NONE	L1 = 0.088 m L2 = 0.081 m	H:0.094m / E:0.000m / N:0.000m

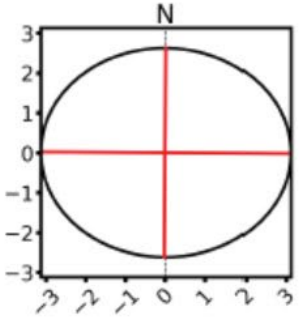
(APC = antenna phase center; ARP = antenna reference point)

NRCan-PPP report (2)

Estimated Position for WAIG1570.22o

	Latitude (+n)	Longitude (+e)	Ell. Height
ITRF14 (2022.4)	-9° 26' 33.66287"	147° 10' 53.04108"	154.649 m
Sigmas(95%)	0.002 m	0.003 m	0.009 m
A priori*	-9° 26' 33.71290"	147° 10' 53.00980"	154.703 m
Estimated – A priori	1.537 m	0.954 m	-0.054 m

95% Error Ellipse (mm)
semi-major: 3 mm
semi-minor: 3 mm
semi-major azimuth: -89° 24' 31.22"



UTM (South)
Zone 55

8956200.131 m (N)
519913.631 m (E)

Scale Factors
0.99960491 (point)
0.99958059 (combined)

AusPOS report (1)

AUSPOS GPS Processing Report

July 6, 2022

This document is a report of the GPS data processing undertaken by the AUSPOS Online GPS Processing Service (version: AUSPOS 2.4) . The AUSPOS Online GPS Processing Service uses International GNSS Service (IGS) products (final, rapid, ultra-rapid depending on availability) to compute precise coordinates in International Terrestrial Reference Frame (ITRF) anywhere on Earth and Geocentric Datum of Australia (GDA) within Australia. The Service is designed to process only dual frequency GPS phase data.

An overview of the GPS processing strategy is included in this report.

Please direct any correspondence to GNSSAnalysis@ga.gov.au

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Geoscience Australia
Home Page: http://www.ga.gov.au

AusPOS report (2)

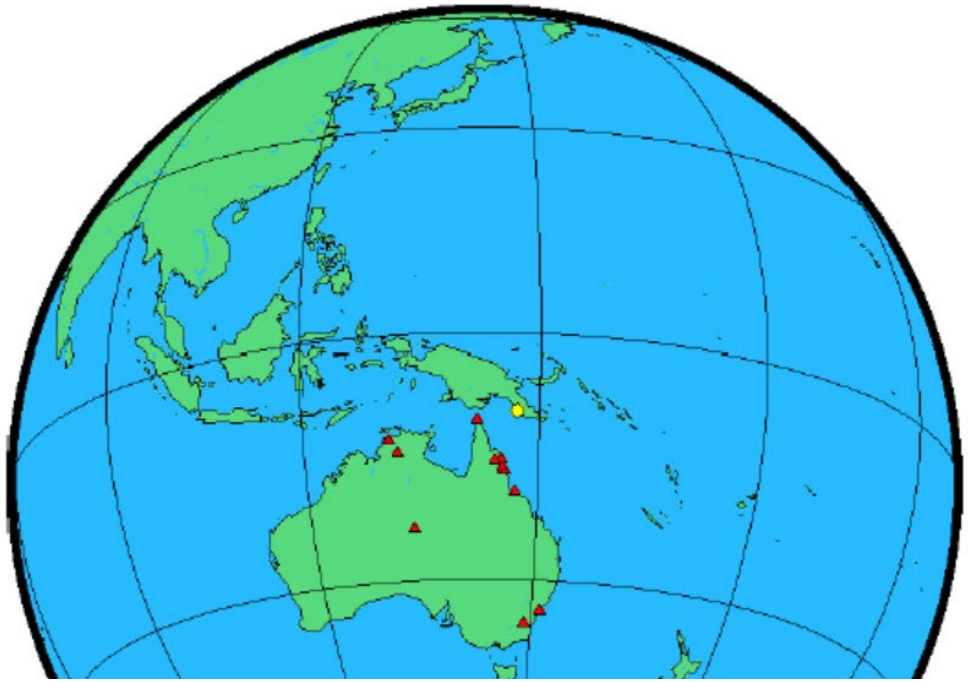
1 User Data

All antenna heights refer to the vertical distance from the Ground Mark to the Antenna Reference Point (ARP).

Station (s)	Submitted File	Antenna Type	Antenna Height (m)	Start Time	End Time
WAIG	WAIG1570.22d	LEIAR10 NONE	0.094	2022/06/06 00:00:00	2022/06/06 23:59:30

AusPOS report (3)

2 Processing Summary



Date	User Stations	Reference Stations	Orbit Type
2022/06/06 00:00:00	WAIG	ALIC CKTN DARW KAT1 LURA MOLY PMCV SYDN TID1 TITG TOW2 WONG	IGS final

AusPOS report (4)

5 Computed Coordinates, ITRF2014

All coordinates are based on the IGS realisation of the ITRF2014 reference frame. All the given ITRF2014 coordinates refer to a mean epoch of the site observation data. All coordinates refer to the Ground Mark.

5.1 Cartesian, ITRF2014

Station	X (m)	Y (m)	Z (m)	ITRF2014 @
WAIG	-5288103.125	3410380.038	-1039516.855	06/06/2022
ALIC	-4052052.829	4212835.964	-2545104.452	06/06/2022
CKTN	-5052215.659	3504869.635	-1689180.668	06/06/2022
DARW	-4091359.701	4684606.385	-1408578.982	06/06/2022

5.2 Geodetic, GRS80 Ellipsoid, ITRF2014

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)
WAIG	-9 26 33.66285	147 10 53.04115	154.656	79.745
ALIC	-23 40 12.39182	133 53 07.88075	603.235	588.091
CKTN	-15 27 34.29725	145 14 59.36822	72.416	8.132
DARW	-12 50 37.30368	131 07 57.88228	125.104	74.644

AusPOS report (5)

5.3 UTM Grid, GRS80 Ellipsoid, ITRF2014

Station	East (m)	North (m)	Zone	Ellipsoidal Height (m)	Derived Above Geoid Height(m)
WAIG	519913.633	8956200.132	55	154.656	79.745
ALIC	386353.317	7381852.443	53	603.235	588.091
CKTN	312225.685	8290082.612	55	72.416	8.132
DARW	731470.161	8579191.332	52	125.104	74.644

5.4 Positional Uncertainty (95% C.L.) - Geodetic, ITRF2014

Station	Longitude(East) (m)	Latitude(North) (m)	Ellipsoidal Height(Up) (m)
WAIG	0.005	0.005	0.012
ALIC	0.004	0.004	0.009
CKTN	0.005	0.005	0.011
DARW	0.005	0.005	0.009

Comparison NRCan-PPP & AusPOS

WAIG	519913.633	8956200.132	55	154.656

UTM (South)
Zone 55

8956200.131 m (N)
519913.631 m (E)

Ell. Height

154.649 m

Transformation to PNG94

PNG94/PNGMG94 Zone 55 from ITRF2014 UTM AusPOS solution			
Usage in Port Moresby, NCD and Central Province ONLY			
Quickclose 20th January 2021		Enter values into purple cells	
		Conversions in Green cells	
Date of observation	Epoch	UTM Site Velocity m/yr	
(dd/mm/yyyy)	(decimal year)	E	N
6/06/2022	2022.430	0.0333	0.0556
ITRF2014 UTM Zone 55 Solution from AusPOS		PNG94/PNGMG94 Zone 55	
UTM E	UTM N	E	N
519913.633	8956200.132	519912.686	8956198.551