Australian Government
Geoscience Australia

Updates to the Australian corner reflector array coordinates and resulting improvements in absolute location error of SAR products

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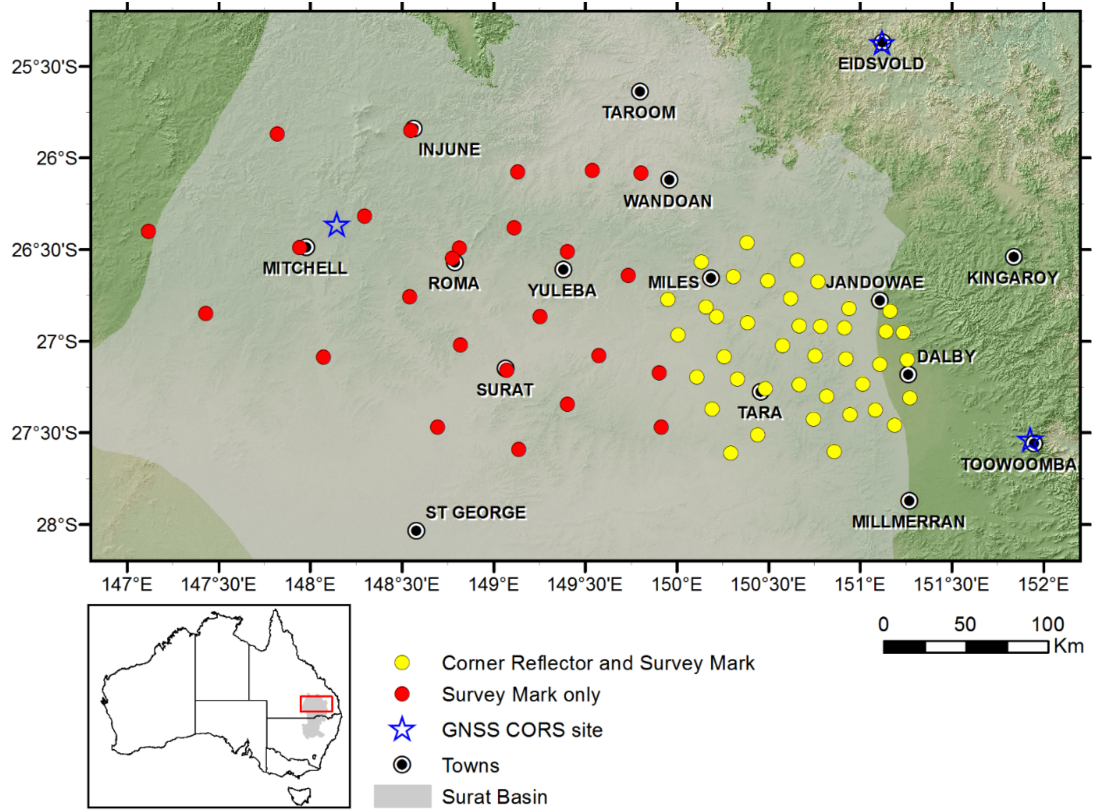
Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

esa
European Space Agency

AGOS CR array - Surat Basin, Queensland



- 40 Corner Reflectors (CR) installed in 2014 in the Surat Basin, Queensland
- Permanent survey mark established close to the CR site for GPS campaigns

CRs providing multi-mission calibration support

The AGOS CR array is used by multiple SAR missions for calibration including the Sentinel-1 constellation under ESA's FRM4SAR initiative

CR coordinates can be accessed from the Point and Distributed Targets Database maintained by the CEOS WGCV SAR Subgroup

CEOS-WGCV – SAR Subgroup
The Committee on Earth Observation Satellites
Working Group on Calibration and Validation
Synthetic Aperture Radar Subgroup

Target Group: *Surat Basin, Queensland, Australia*

Maintainer

Medhavy Thankappan (Medhavy.Thankappan@ga.gov.au)

Contact Details

There are two maintainers for this target group:

- Medhavy Thankappan (Medhavy.Thankappan@ga.gov.au)
- Matt Garthwaite (Matt.Garthwaite@ga.gov.au)

Description

This target group of 40 corner reflectors is a regional-scale geodetic network that has been installed by Geoscience Australia in the Surat Basin, Queensland, Australia. The permanent installation of corner reflectors was completed in November 2014.

The network incorporates 65 survey marks and 40 radar corner reflectors to enable the combination of Global Navigation Satellite System measurements with remotely sensed surface deformation maps derived using the Interferometric Synthetic Aperture Radar technique. The combination of these geodetic techniques in this region will bring an enhanced understanding of how resource extraction affects the ground surface.

Although their main purpose is for geodetic monitoring, by design the corner reflectors are also able to support ongoing radiometric calibration and geometric validation of X, C and L-band SAR imagery.

Please check site Surat Basin 26 to see an **image of a typical 1.5 m triangular trihedral corner reflector**.

Further details about the corner reflector array are given in the following papers:

- M. C. Garthwaite , M. Hazelwood , S. Nancarrow , A. Hislop , J. H. Dawson: *A regional geodetic network to monitor ground surface response to resource extraction in the northern Surat Basin, Queensland*, Australian Journal of Earth Sciences, Vol. 62, Iss. 4, 2015. Freely available from: http://www.tandfonline.com/doi/full/10.1080/08120099.2015.1040073.
- M. C. Garthwaite, S. Nancarrow, A. Hislop, M. Thankappan, J. Dawson, S. Lawrie: *The design of radar corner reflectors for the Australian Geophysical Observing System*, Record 2015/03, Geoscience Australia, 2015. Freely available from: http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_82751.

AGOS CR array coordinates

- Original survey measured this point
- CR apex is required for geometric cal/val
- All 40 sites re-surveyed in May/June 2018
- New CR apex positions available now

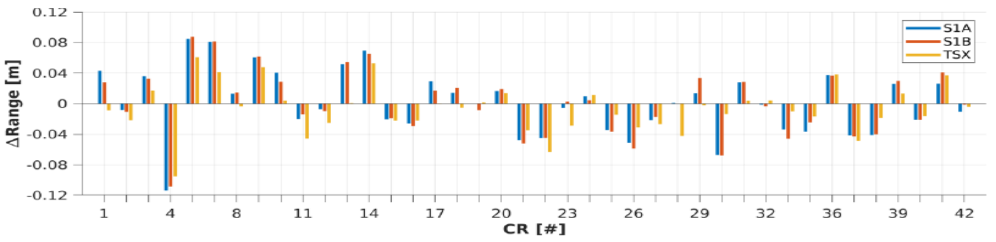
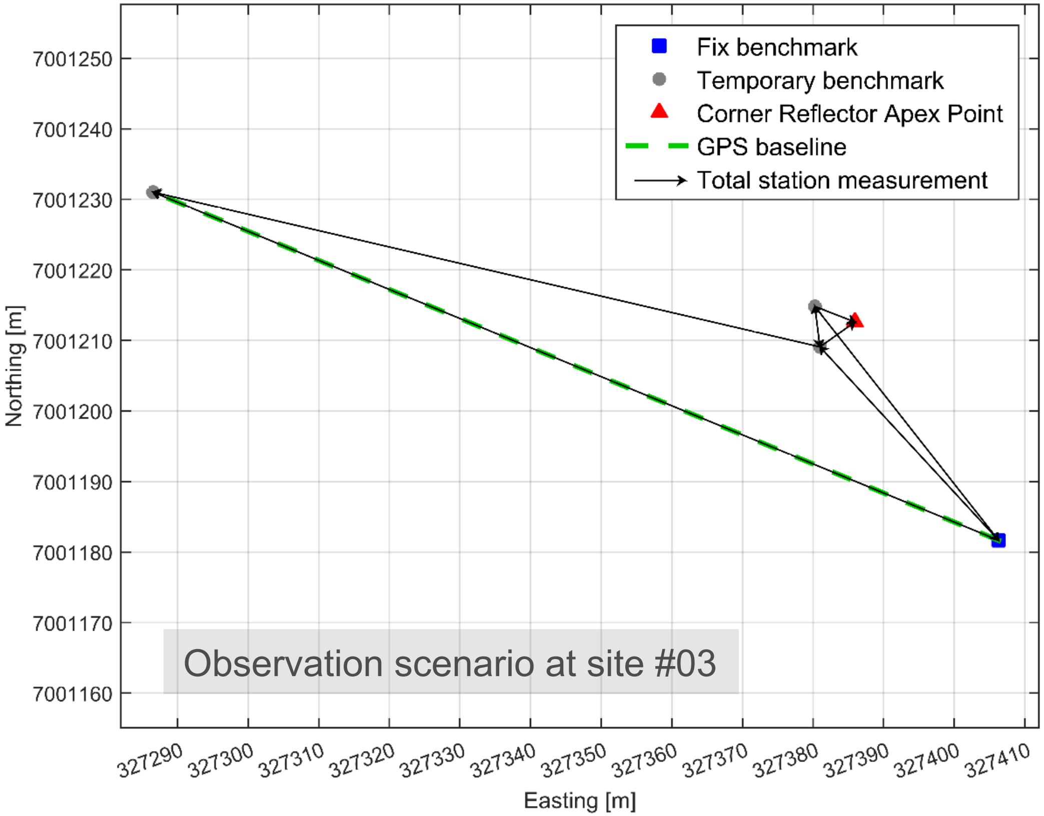


Figure 23: Average range offset for the individual CRs computed from range residuals of the experimentally calibrated Sentinel-1 IW data (see Table 8) and the TerraSAR-X ScanSar data (range results of Figure 13).

Results courtesy C. Gisinger, DLR

2018 re-survey: precise coordinates for CR apex points

- Terrestrial observations using GPS and total station measurements.
- Precise 3D coordinates of permanent survey marks in GDA2020 reference frame (Geodetic Datum of Australia) resulting from two GPS campaign measurements performed in 2015 and 2016.
- Geodetic adjustment of local network observed in 2018 to derive precise coordinates for the CR Apex Points.



GPS measurements

- 1h of simultaneous GPS observations at each site at the permanent survey mark and a temporary mark (baseline: ~ 100 m).


Permanent benchmark at site #03


Temporary mark at site #03

Total station measurements

- Total station measurements performed at the permanent survey mark and at two temporary marks next to the CR.

Example set-up at site #30

Accessing the apex point

- Since the Apex Point cannot be observed directly, an offset measurement to a plumb hanging vertically from the drainage hole in the CR was used.


Survey stations at site #03


Zoom to Apex Point at site #03

Results

- Site list containing CR Apex coordinates, velocities (due to plate motion) and CR boresight orientation:

Name	Latitude	Longitude	Height	X	Y	Z	veloX	veloY	veloZ	Azimuth	Elevation
SB01-CRApex	-26.834709850	151.165603881	409.4631	-4989394.0492	2746844.3972	-2862070.0918	-0.0325	-0.0083	0.0487	257.11	53.32
SB02-CRApex	-26.951633111	151.237612686	432.7115	-4987723.0940	2737761.6635	-2873635.5864	-0.0325	-0.0082	0.0486	256.21	53.33
SB03-CRApex	-27.100731831	151.258808883	391.8734	-4982121.1238	2732288.8146	-2888334.6256	-0.0326	-0.0081	0.0485	258.46	54.34
SB04-CRApex	-27.308871397	151.271959122	385.2527	-4973496.3145	2726074.1833	-2908844.8086	-0.0326	-0.0079	0.0484	258.51	54.67
SB05-CRApex	-27.456930261	151.190829536	403.0121	-4963032.7828	2729484.8882	-2923421.9305	-0.0327	-0.0077	0.0484	258.20	55.36

...

- Metadata information on the site list:

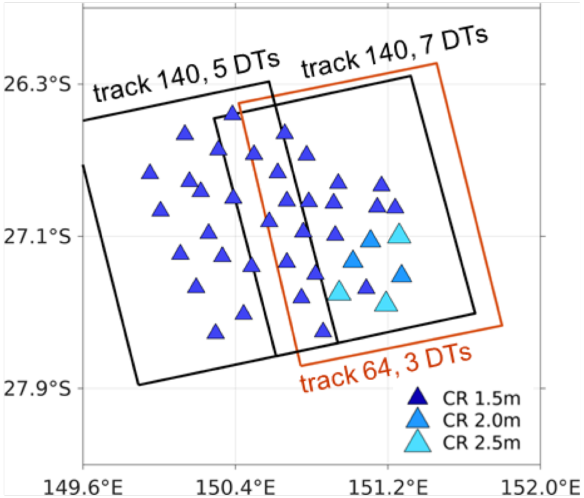
Column name	Unit	Comments
Name	-	Name of Corner Reflector Apex Point (SB: Surat Basin)
Latitude	degrees	Geographic latitude in decimal degrees
Longitude	degrees	Geographic longitude in decimal degrees
Height	metres	Ellipsoidal height
X	metres	Geocentric, cartesian coordinate (Earth-centred, Earth-fixed)
Y	metres	Geocentric, cartesian coordinate (Earth-centred, Earth-fixed)
Z	metres	Geocentric, cartesian coordinate (Earth-centred, Earth-fixed)
veloX	metres/yr	Velocity at XYZ location according to plate motion model published in GDA2020 Technical Manual
veloY	metres/yr	Velocity at XYZ location according to plate motion model published in GDA2020 Technical Manual
veloZ	metres/yr	Velocity at XYZ location according to plate motion model published in GDA2020 Technical Manual
Azimuth	degrees	Azimuth of corner reflector boresight vector (0 degree: North, 90 degrees: East)
Elevation	degrees	Elevation of corner reflector boresight vector (0 degree: local horizon, 90 degrees: local zenith)

All coordinates are given in the GDA2020 reference frame. GDA2020 is based on a realisation of the ITRF2014 (ITRF2014; Altamimi et al., 2016) ...

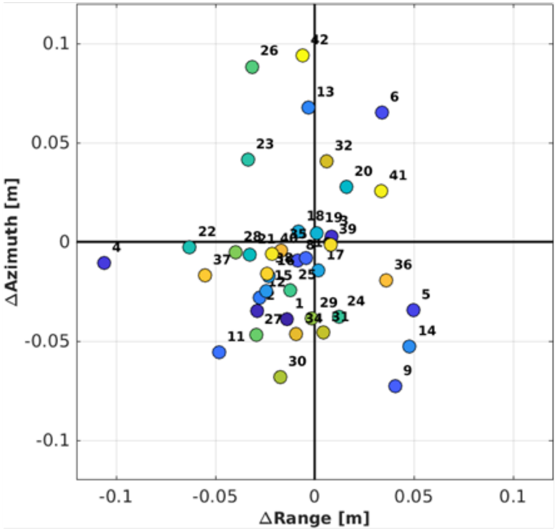
Validation: TerraSAR-X geolocation analysis

TerraSAR-X ScanSAR data for the entire array (east & west to get coverage; 2 tracks)

TerraSAR-X ScanSAR Coverage 04/17 – 02/18



TerraSAR-X ScanSAR ALE: Old Coordinates



Coordinates from first survey after installation plus offsets for CR apex

Range [m]	Azimuth [m]
-0.012 ± 0.041	-0.010 ± 0.090

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German Aerospace Center

Analysis, results provided by Christoph Gisinger

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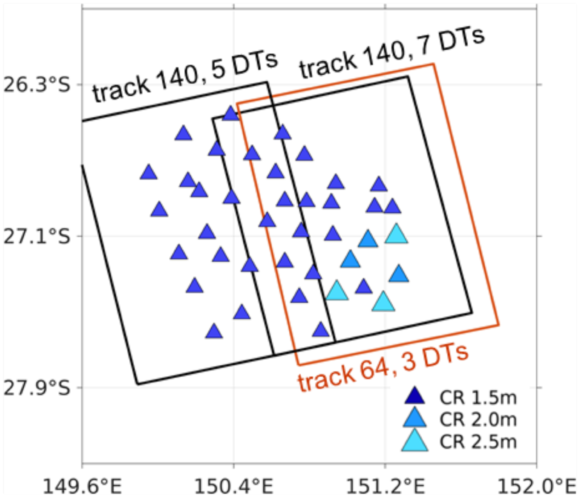
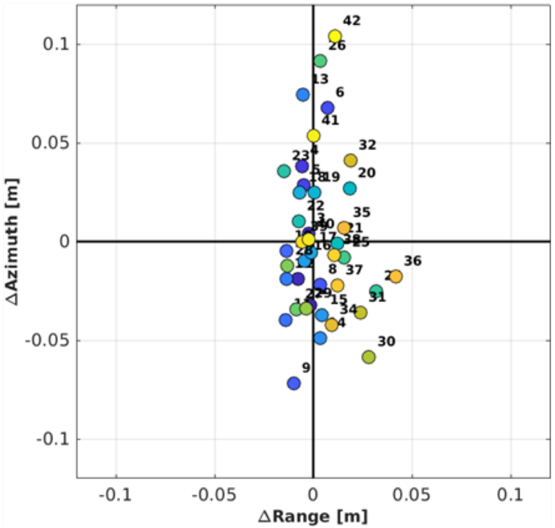


TerraSAR-X ScanSAR ALE: New Coordinates



All coordinates re-processed with new 2019 GA GNSS benchmark coordinates

Mean & STD across all CRs:

Range [m]	Azimuth [m]
-0.012 ± 0.041	-0.010 ± 0.090
0.000 ± 0.026	-0.002 ± 0.090

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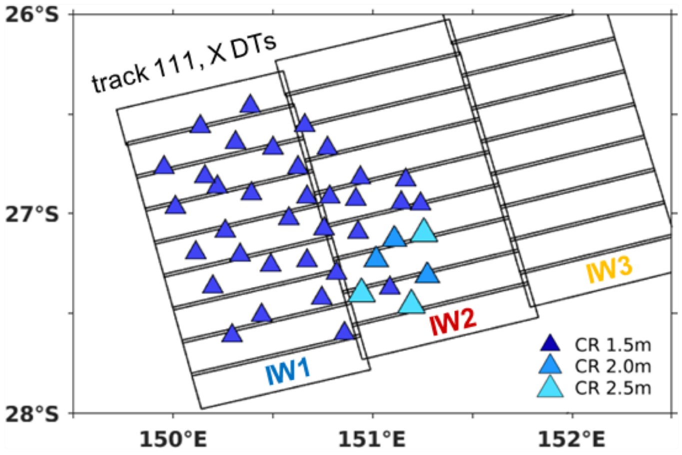
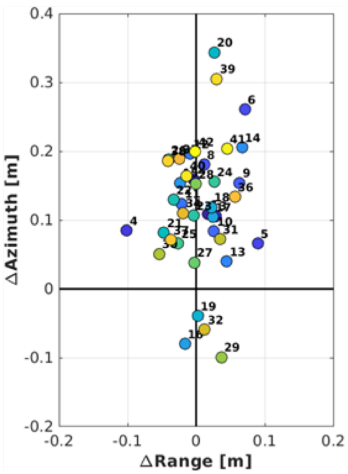
Validation: Sentinel-1 geolocation analysis

Sentinel-1 IW repeat pass data covers the entire array (analysis done with S1B only)

Sentinel-1 Coverage (Burst / Slice of IW) 10/16 – 10/19



Sentinel-1 IW ALE: Old Coordinates



Coordinates from first survey after installation plus offsets for CR apex

Range [m]	Azimuth [m]
0.005 ± 0.055	0.123 ± 0.249

DLR Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center

Analysis, results provided by Christoph Gisinger

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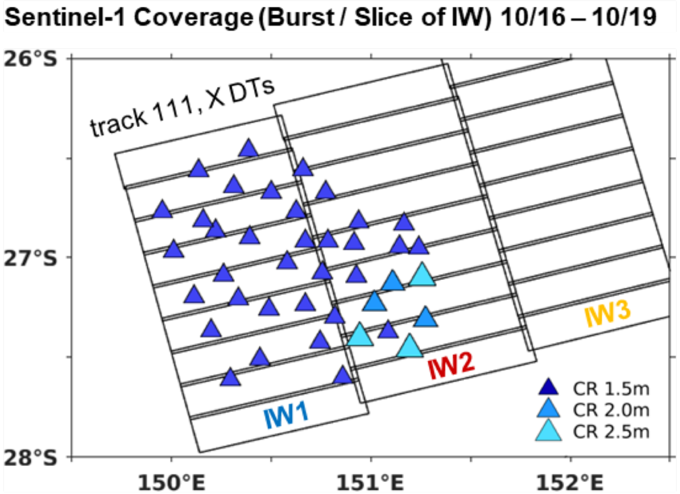

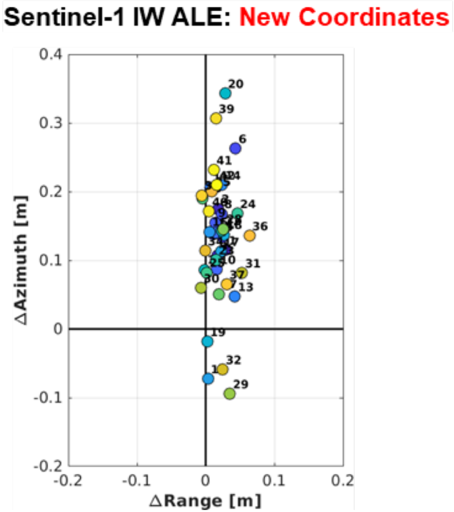

All coordinates re-processed with new 2019 GA GNSS benchmark coordinates

Range [m]	Azimuth [m]
0.005 ± 0.055	0.123 ± 0.249
0.018 ± 0.043	0.131 ± 0.249

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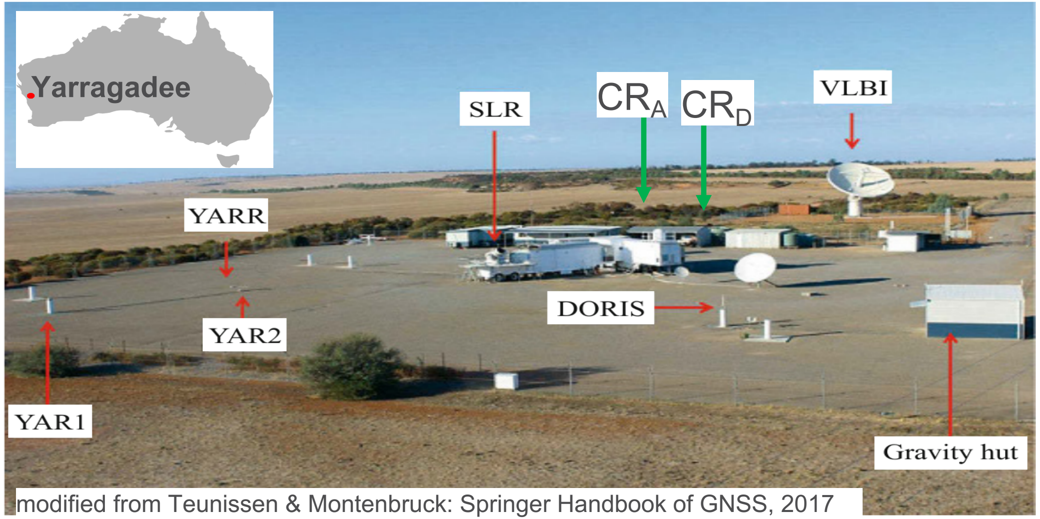
Analysis, results provided by Christoph Gisinger

Permanent SAR corner reflectors at Yarragadee

Yarragadee is one of the few fundamental geodetic stations that co-locates all four geodetic techniques (GNSS, VLBI, SLR, DORIS) . In August 2018 station equipped with two trihedral CRs (1.5m inner-leg), permanently mounted on deep concrete foundations, with one CR facing east and the other CR facing west to support both ascending and descending passes

The CR vertical boresight was aligned for 40° incidence angle to allow measurements from all radar beams between 25° and 55° incidence angle

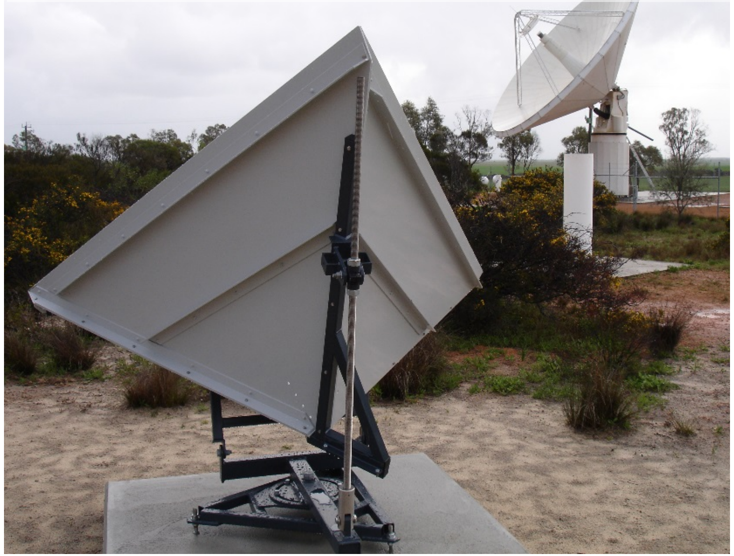


modified from Teunissen & Montenbruck: Springer Handbook of GNSS, 2017

Survey of Yarragadee CRs

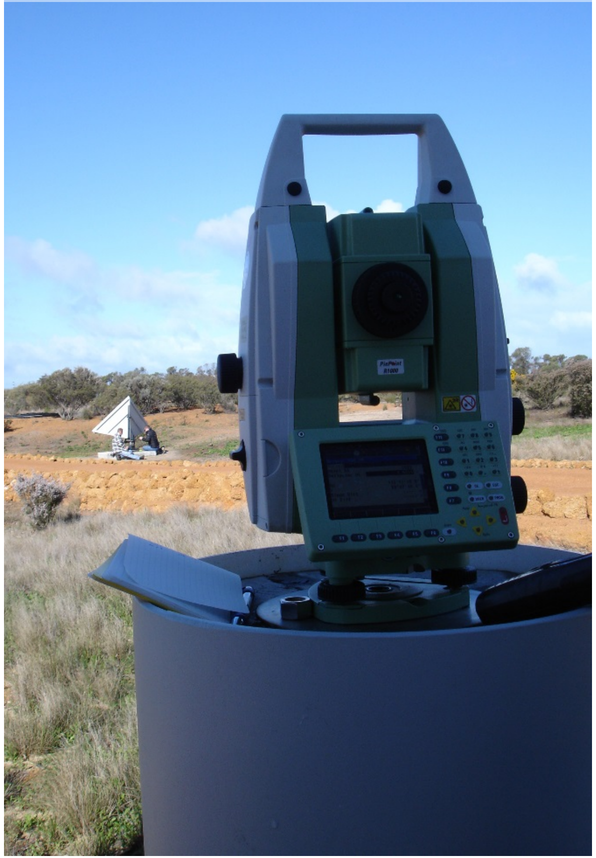
- A similar survey was performed for the two CRs installed in 2018 at Yarragadee Geodetic Observatory, Western Australia.
- Here, the total station measurements to the CR Apex Points could be performed from two pillars with known coordinates.

CR at Yarragadee Geodetic Observatory



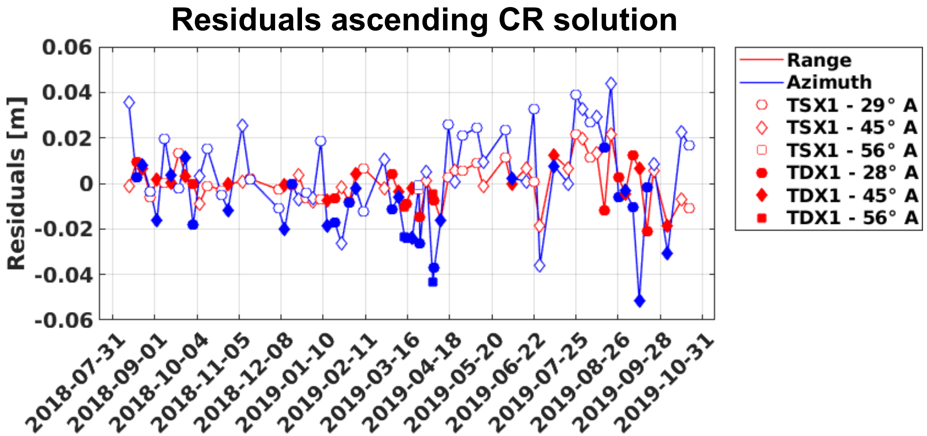
[m]	X	Y	Z
asc CR	-2388932.4088	5043314.0074	-3078610.7342
desc CR	-2388946.0526	5043329.6596	-3078571.6600

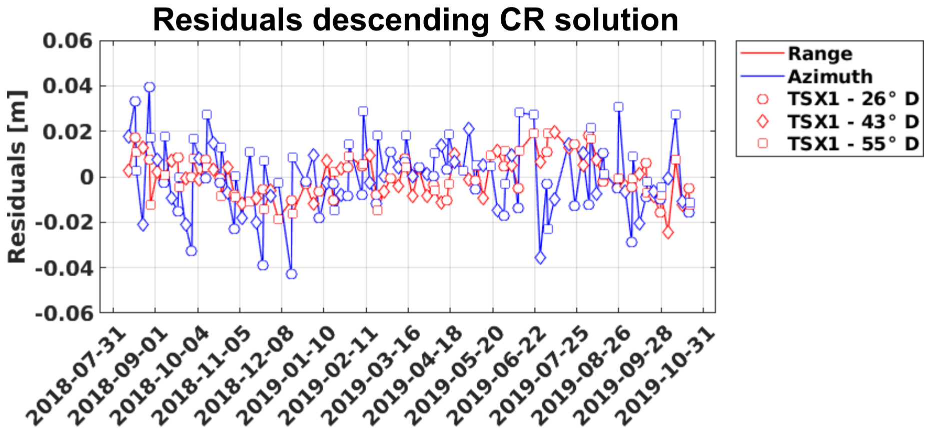
Total station survey at Yarragadee



Validation: TerraSAR-X positioning results- Yarragadee

Least squares observation residuals for TSX/TDX positioning results





Difference SAR - local tie survey (ITRF2014, 2018-08-14), converted to local NEU, and 95% confidence of SAR solution

CR	# DT	ΔN [m]	ΔE [m]	ΔU [m]	s_N [m]	s_E [m]	s_u [m]
CR_A	68	-0.0132	-0.0192	-0.0004	0.0080	0.0169	0.0126
CR_D	102	-0.0183	-0.0213	0.0162	0.0050	0.0100	0.0079

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Analysis, results provided by Christoph Gisinger

Summary

- For AGOS CRs, improvement of the re-surveyed coordinates clearly visible in TSX ScanSAR range ALE
- TSX Azimuth ALE mainly limited by ScanSAR data resolution
- Improvement from the new coordinates are also visible in the Sentinel-1 range ALE results
- Yarragadee CR coordinates independently verified by TSX 3D SAR solution, results within 2 cm
- Updated positions for CRs will enable better consistency in the quality of SAR data calibration for multiple sensors

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