



Australian Government  
Geoscience Australia



# Australian Infrastructure Supporting Global EO Calibration and Validation

Medhavy Thankappan, Matthew Adams



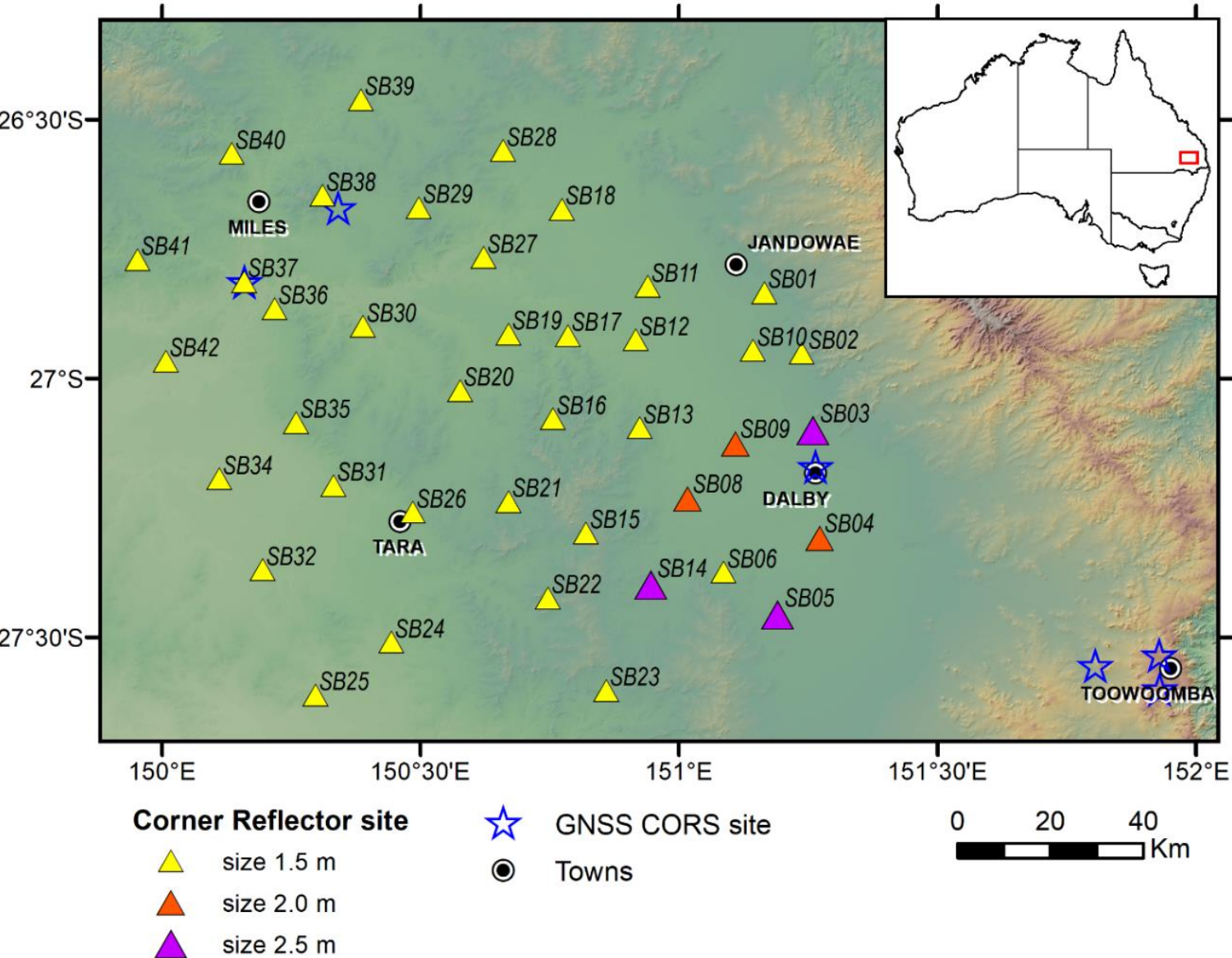
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# Outline

- ❖ Synthetic Aperture Radar calibration
- ❖ Calibration support for Landsat Next
- ❖ Supporting the Pandonia network

# Queensland Corner Reflector Array – Surat Basin, Australia



- ❖ 40 triangular trihedral Corner Reflectors (CR) installed in 2014 in south-east Queensland
- ❖ Co-located high-stability benchmark at each CR site for GPS campaigns



# Geolocation quality monitoring for Sentinel-1 using QCRA

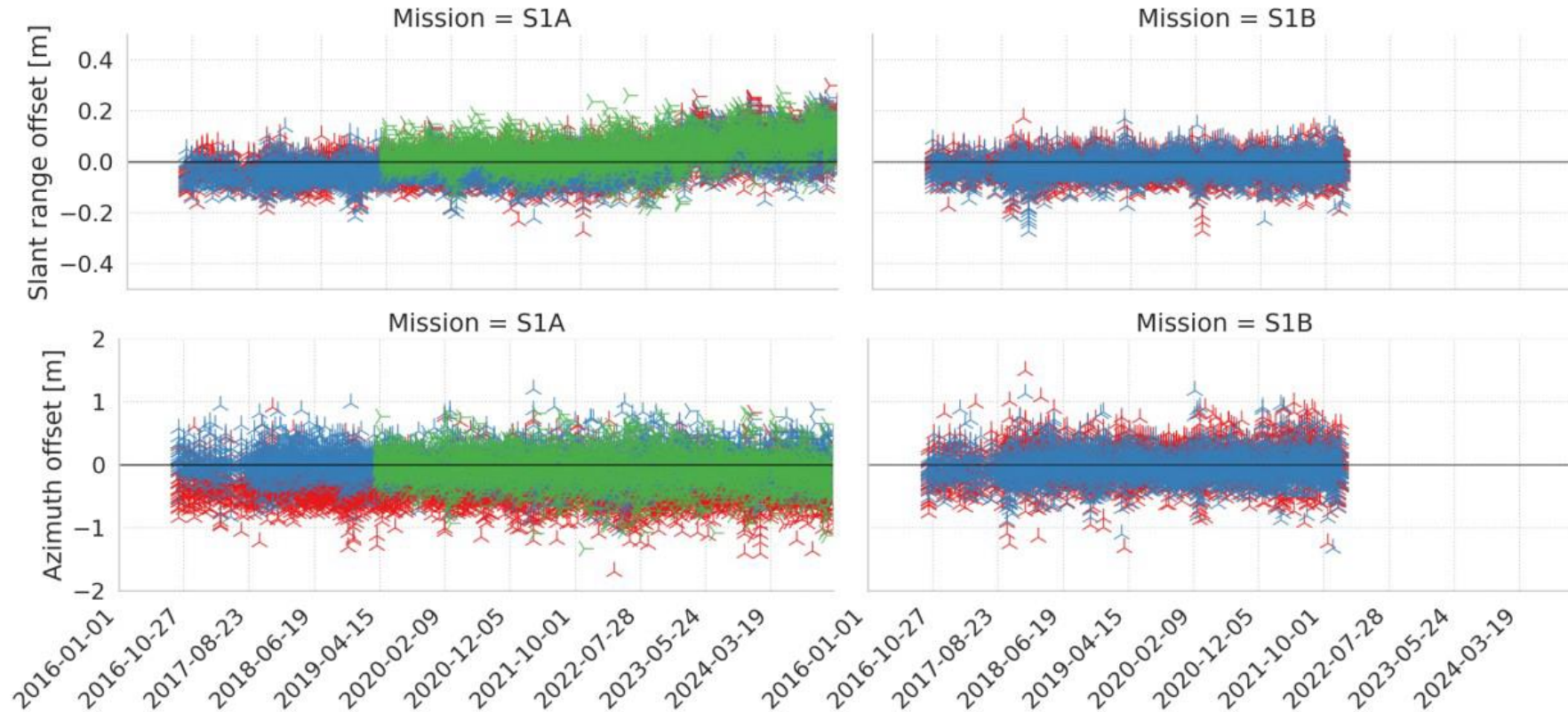
- ❖ Unique infrastructure supporting SAR calibration managed by Geoscience Australia
- ❖ By design, the QCRA conforms to FRM4SAR protocols
- ❖ Maintenance schedule – current Nov 2025

*“The stability and reliability of the wide-area test site in Australia (Surat Basin) makes it ideal to perform geometric calibration and validation of SAR sensors. The site includes 40 trihedral CRs covering an area of nearly 13000 km<sup>2</sup>, most of them with 1.5m side lengths and three targets with 2.0m and 2.5m side lengths, respectively. Their positions were confirmed by several research groups to be both accurate and stable enough for precise geolocation monitoring over long periods and were accurately re-surveyed in 2018 by its maintainer Geoscience Australia [S1-RD-22]. The site has only one significant disadvantage, i.e., all reflectors are oriented towards an ascending orbit, not allowing to easily detect azimuth timing errors via ascending/descending comparisons. For this reason (among others), observations from other sites remain important, especially as a cross-reference complementing larger, longer-term sites such as Surat Basin.”*

**S-1 Annual Performance Report for 2024 SAR MPC**



# Extended ALE time series for Sentinel-1A & B products over QCRA



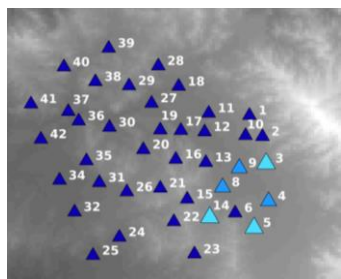
**S-1A and S1-B IW SLC ALE time series for products over the QCRA site acquired between Oct 2016 and Dec 2024, with post-processing corrections (S1 MPC Report 2024)**

# Sentinel-1 SAR sensor geometric validation

Analysis, results provided by Christoph Gisinger, DLR



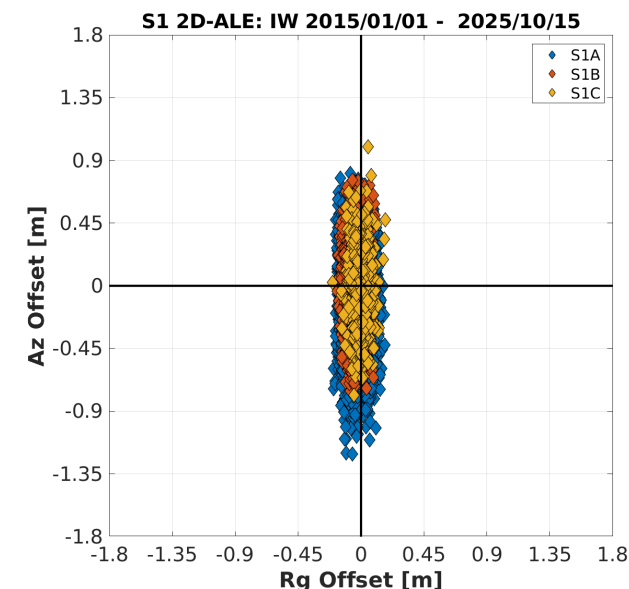
## Australian CR Array



## 40 CRs - ASC

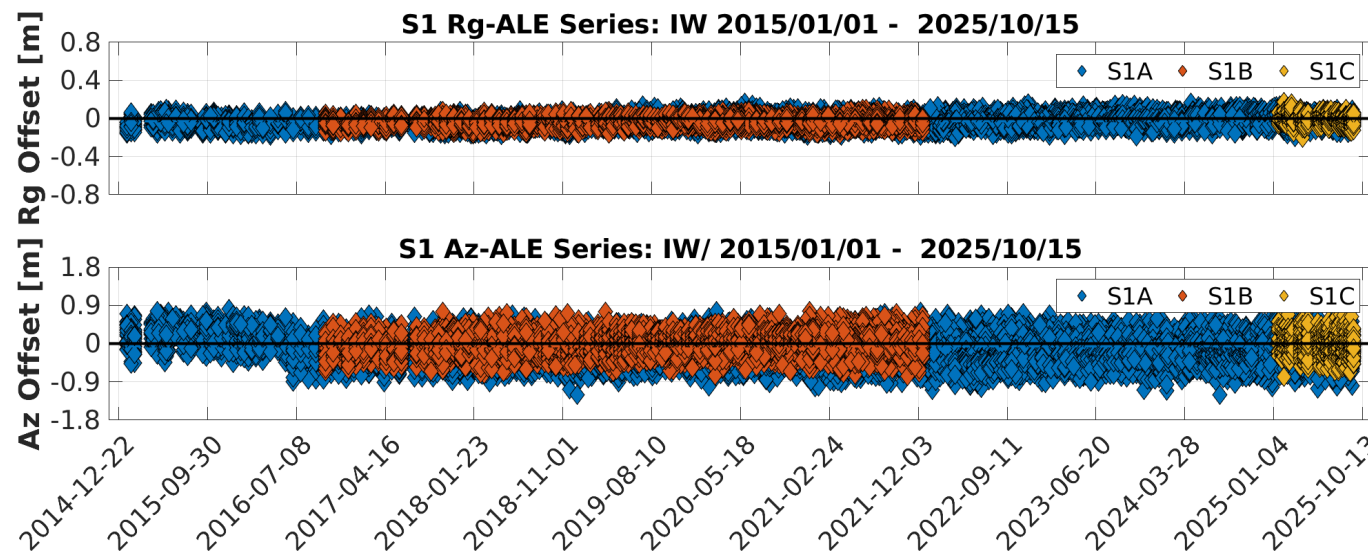
- ❖ Interferometric Wide-swath data
- ❖ Rg/Az: 3 x 22m @ 250 x ... km

	Rg ALE [m]	Az ALE [m]
S1	$-0.031 \pm 0.049$	$-0.082 \pm 0.274$
S1A	$-0.031 \pm 0.052$	$-0.115 \pm 0.286$
S1B	$-0.036 \pm 0.039$	$-0.006 \pm 0.225$
S1C	$0.000 \pm 0.049$	$-0.021 \pm 0.260$

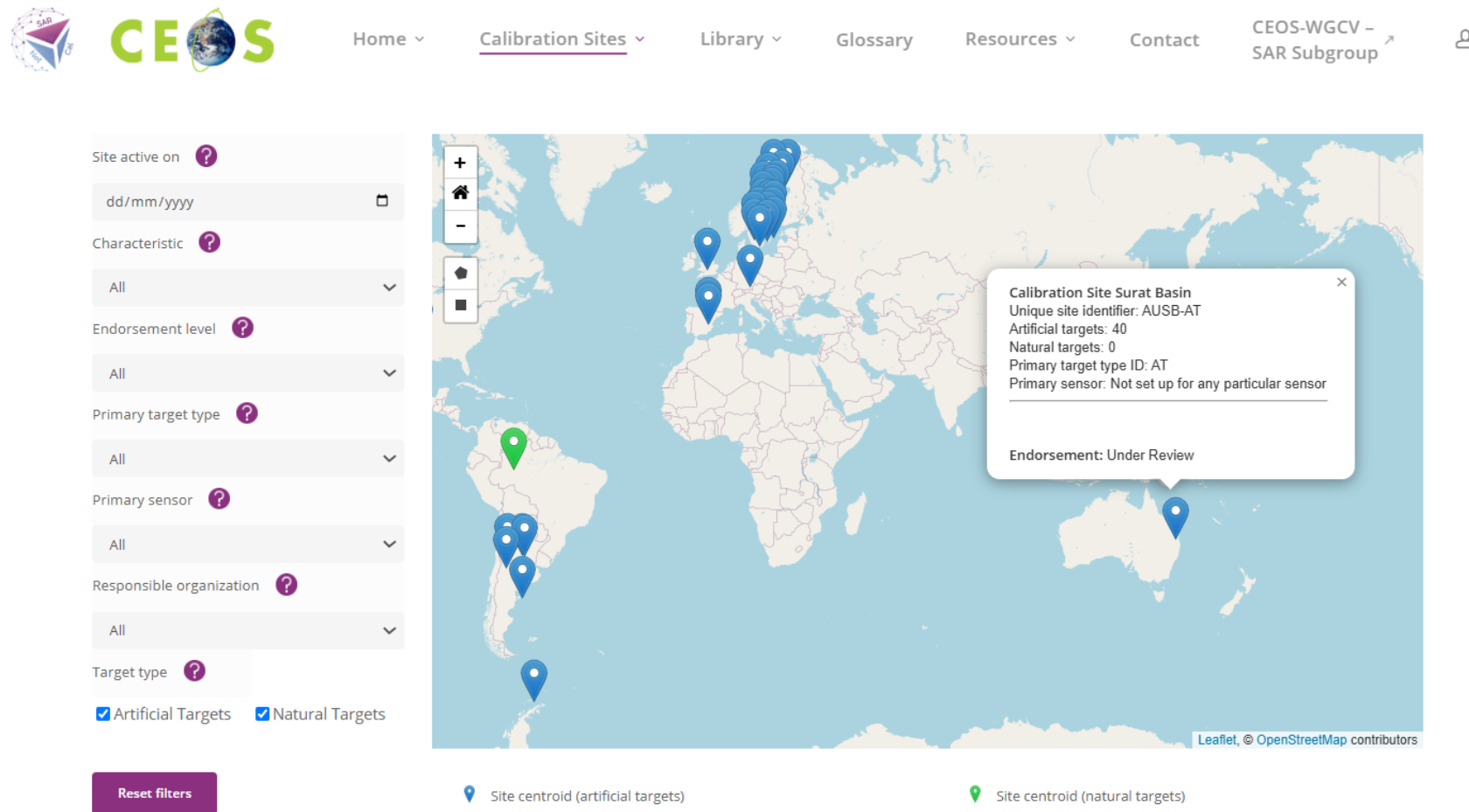


## SAR image versus CR reference positions:

- ❖ Atmosph. path delay corrections
  - ❖ Solid Earth deformations
  - ❖ Sensor calibration constants
  - ❖ S-1 SAR system corrections
- Range / Azimuth residuals
- Statistical outliers removed



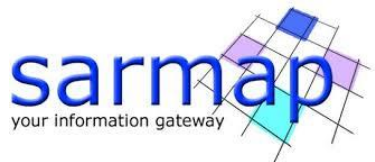
# QCRA submission by GA to SARCalNet (*Under Review*)



*Publication:*

*T. Fuhrmann, J. Batchelor, T. McCall, M.C. Garthwaite (2020), Positions and orientations for the Queensland corner reflector array, Australia <https://ecat.ga.gov.au/geonetwork/srv/api/records/c7bdc9d0-0a2a-4cb9-8224-0f0bb2bd7c37>*

# Who is using the QCRA?



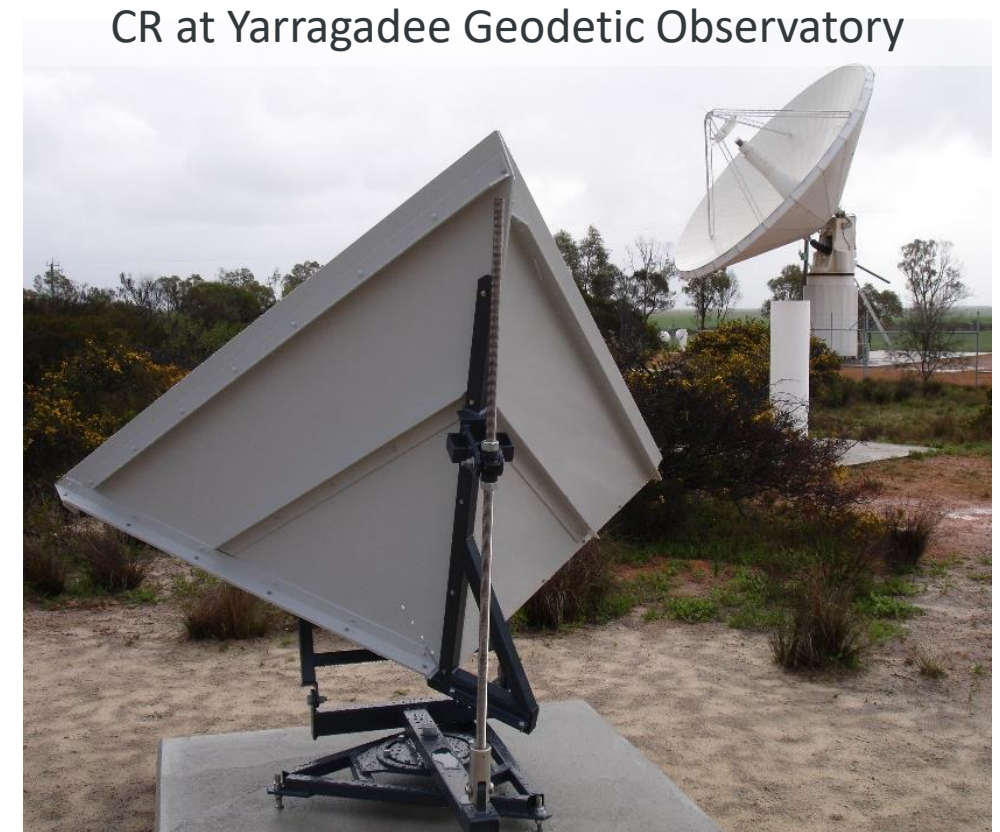
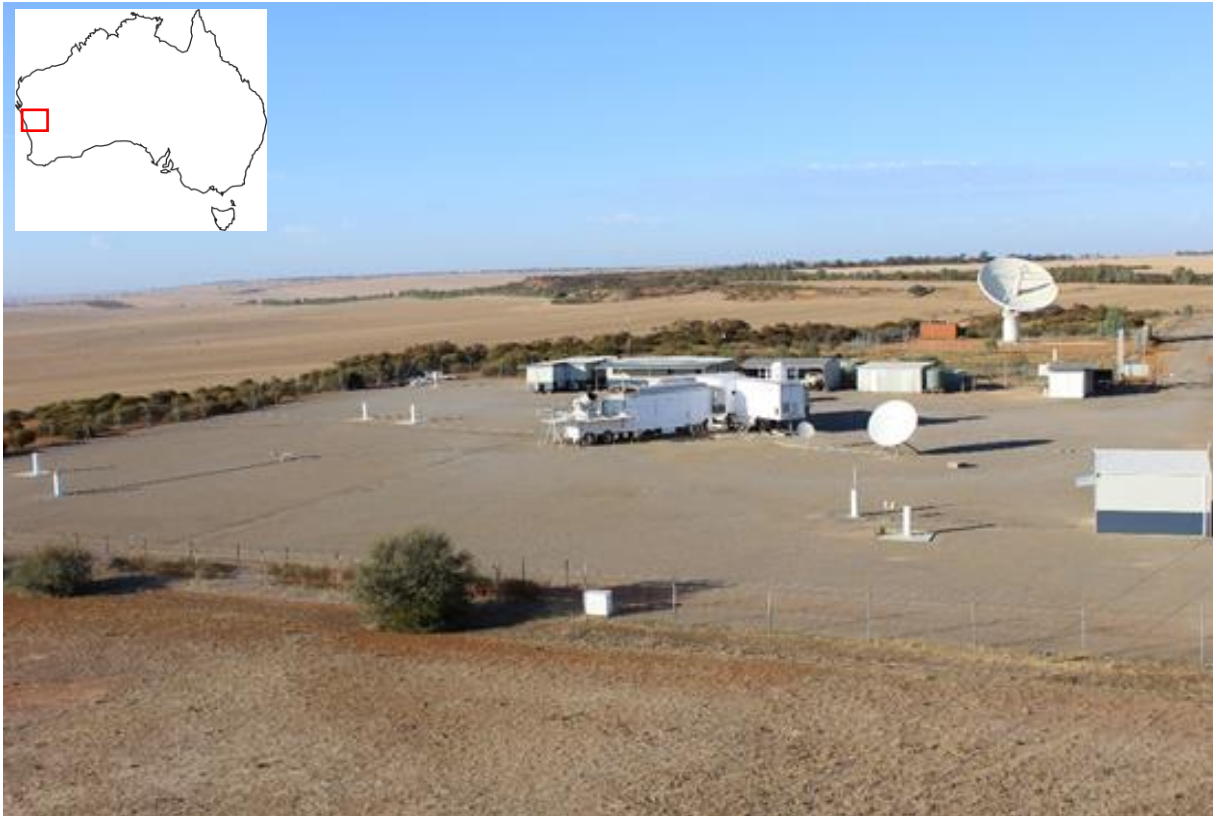
QCRA in the news

<https://www.auscope.org.au/impact-posts/ten-years-on-the-radar>



# Permanent SAR corner reflectors at Yarragadee

- ❖ Yarragadee is one of the few fundamental geodetic stations (YGO) in the world using collocated instruments / techniques for GNSS, SLR, VLBI, DORIS.
- ❖ One ascending and one descending trihedral CRs (1.5m inner-leg), permanently installed at YGO in August 2018





# Survey by GA at the Yarragadee site in July 2025



# Preliminary results of July 2025 survey at Yarragadee

Ascending	X	Y	Z
CR_A 2018	-2388932.409	5043314.007	-3078610.734
CR_A 2025	-2388932.428	5043314.019	-3078610.751
Delta	<b>-0.019</b>	<b>0.012</b>	<b>-0.017</b>
	Azimuth	Elevation	BoresightEI*
	254°30'	14°50'	50°10'

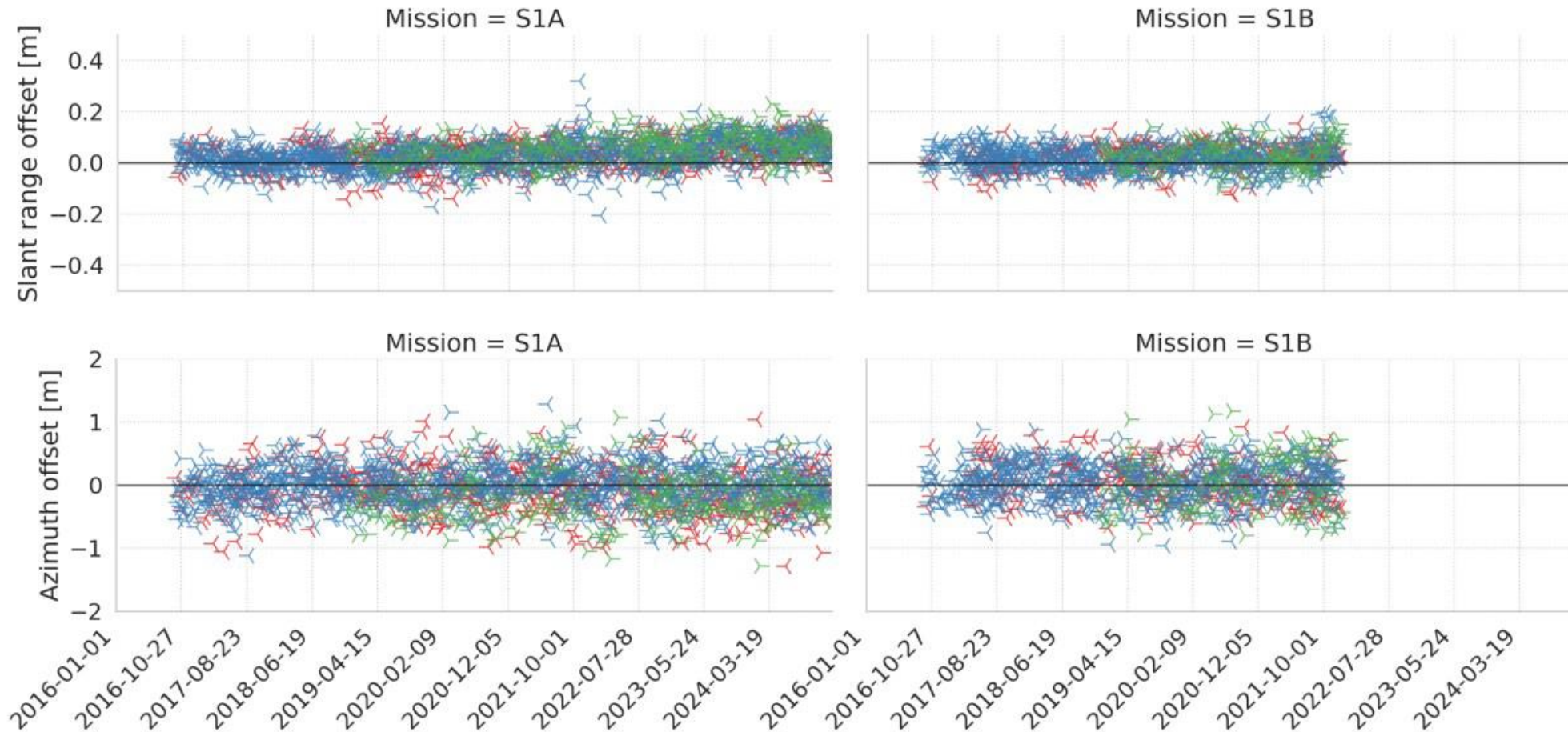
Descending	X	Y	Z
CR_D 2018	-2388946.053	5043329.660	-3078571.660
CR_D 2025	-2388946.064	5043329.685	-3078571.676
Delta	<b>-0.012</b>	<b>0.025</b>	<b>-0.015</b>
	Azimuth	Elevation	BoresightEI*
	101°50'	14°40'	49°50'

- ❖ Results are preliminary and are not yet published
- ❖ Comparison has been made to coordinates observed in 2018, and provided in GDA2020
- ❖ 2025 survey showed agreement with previous results
- ❖ This result likely improves on the previous result, with a longer baseline for datum used in 2025

ITRF2014 at epoch 2020.0 (per GDA2020)



# Extended ALE time series for Sentinel-1A & B products over YGO



S-1A and S1-B IW SLC ALE time series for products over the Geodetic Observatory sites (Wettzell, Metsähovi, Yarragadee, Côte d’Azur) acquired between Oct 2016 and Dec 2024, with post-processing corrections (S1 MPC Report 2024)



# TerraSAR-X SAR sensor geometric validation

Analysis, results provided by Christoph Gisinger, DLR



## Yarragadee Geodetic Station



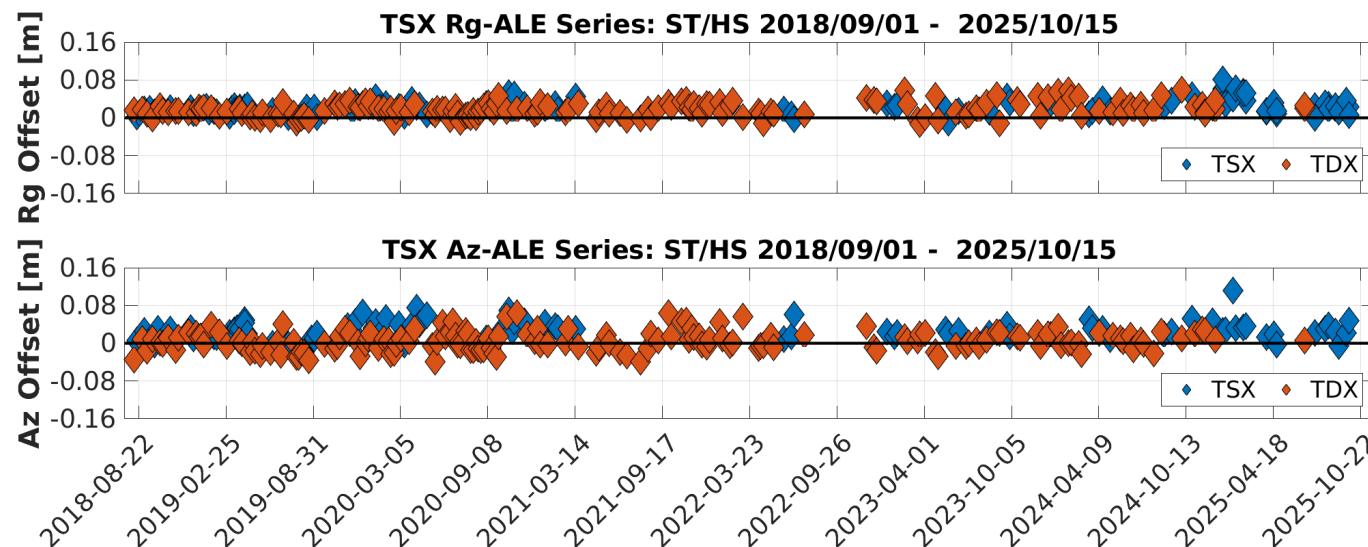
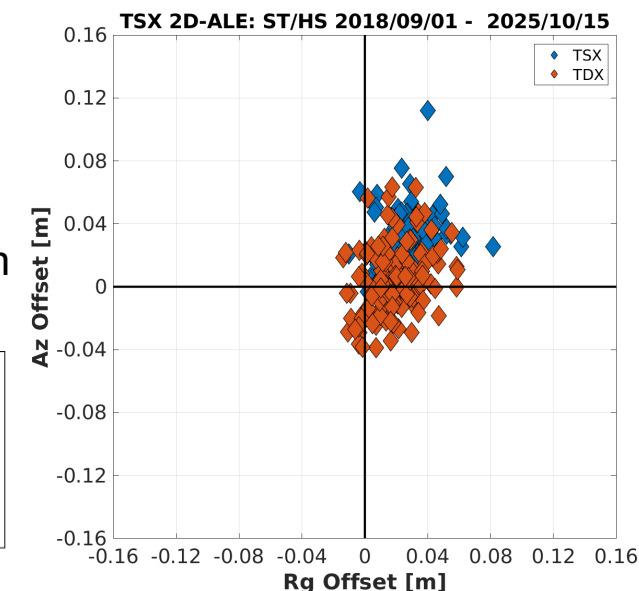
### SAR image versus CR reference positions:

- ❖ Atmosph. path delay corrections
- ❖ Solid Earth deformations
- ❖ Sensor calibration constants
- Range / Azimuth residuals
- Statistical outliers removed

## CR - ASC

- ❖ Staring / High-res Spotlight data
- ❖ Rg/Az: 0.6 x 0.25/1m @ 7 x 3/5km

	Rg ALE [m]	Az ALE [m]
TSX	0.020 ± 0.015	0.014 ± 0.023
TDX	0.024 ± 0.015	0.028 ± 0.019
TSX	0.018 ± 0.015	0.005 ± 0.020



# TerraSAR-X SAR sensor geometric validation

Analysis, results provided by Christoph Gisinger, DLR



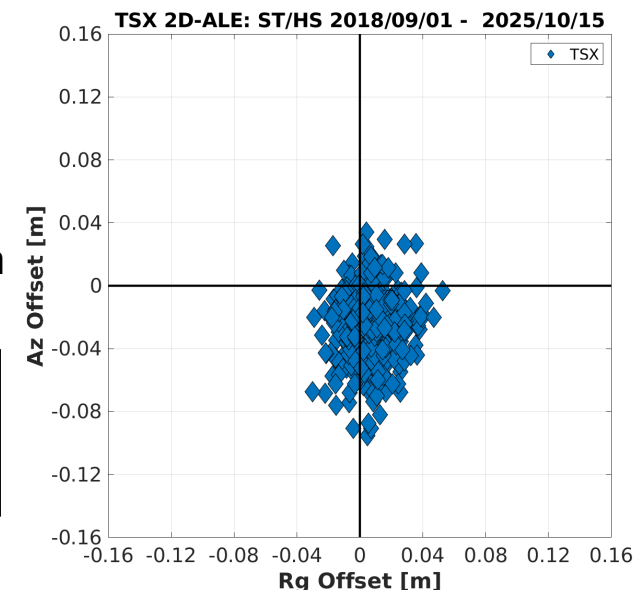
## Yarragadee Geodetic Station



### CR - DESC

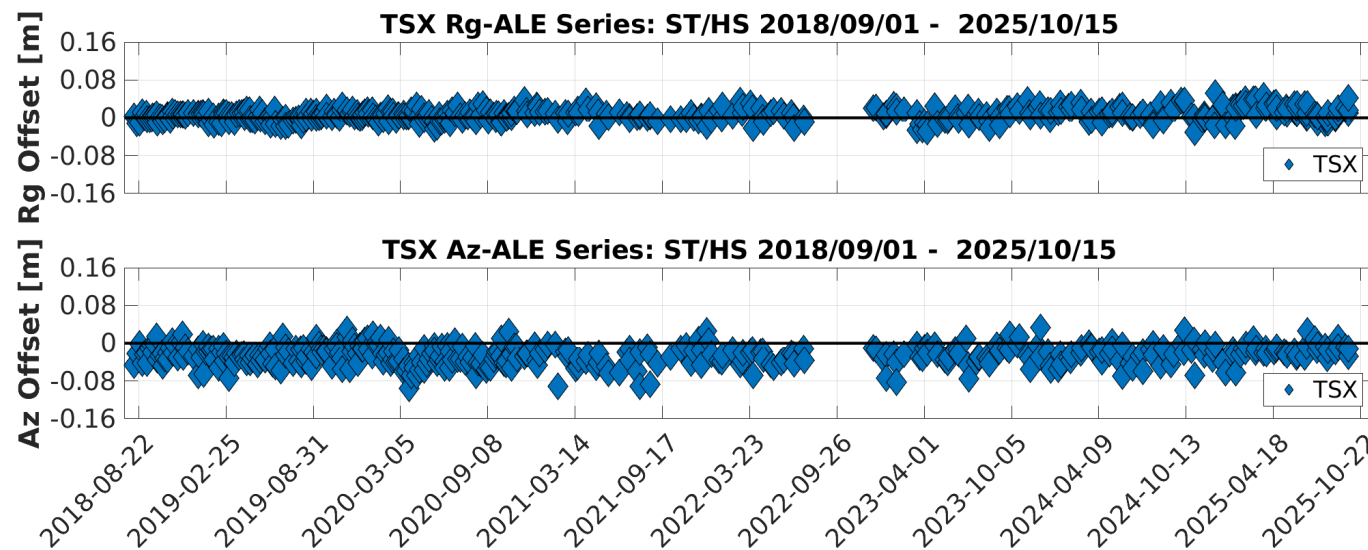
- ❖ Staring / High-res Spotlight data
- ❖ Rg/Az: 0.6 x 0.25/1m @ 7 x 3/5km

	Rg ALE [m]	Az ALE [m]
TSX	$0.007 \pm 0.013$	$-0.024 \pm 0.021$
TSX	$0.007 \pm 0.013$	$-0.024 \pm 0.021$



### SAR image versus CR reference positions:

- ❖ Atmosph. path delay corrections
- ❖ Solid Earth deformations
- ❖ Sensor calibration constants
- Range / Azimuth residuals
- Statistical outliers removed



# Sentinel-1 SAR sensor geometric validation

Analysis, results provided by Christoph Gisinger, DLR



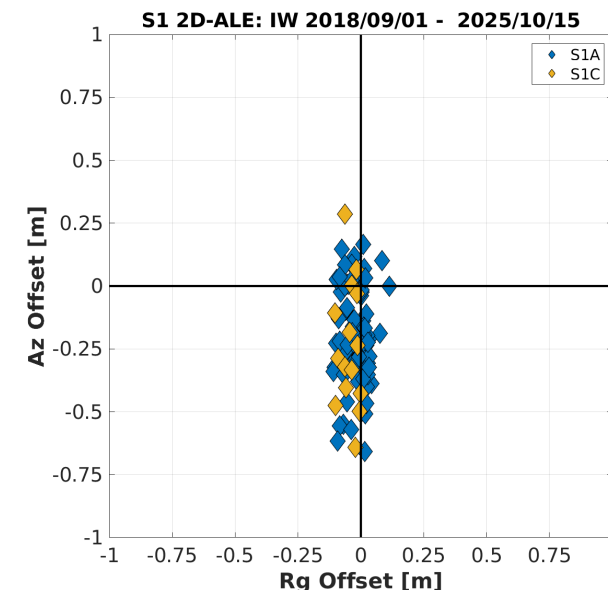
## Yarragadee Geodetic Station



### CR - ASC

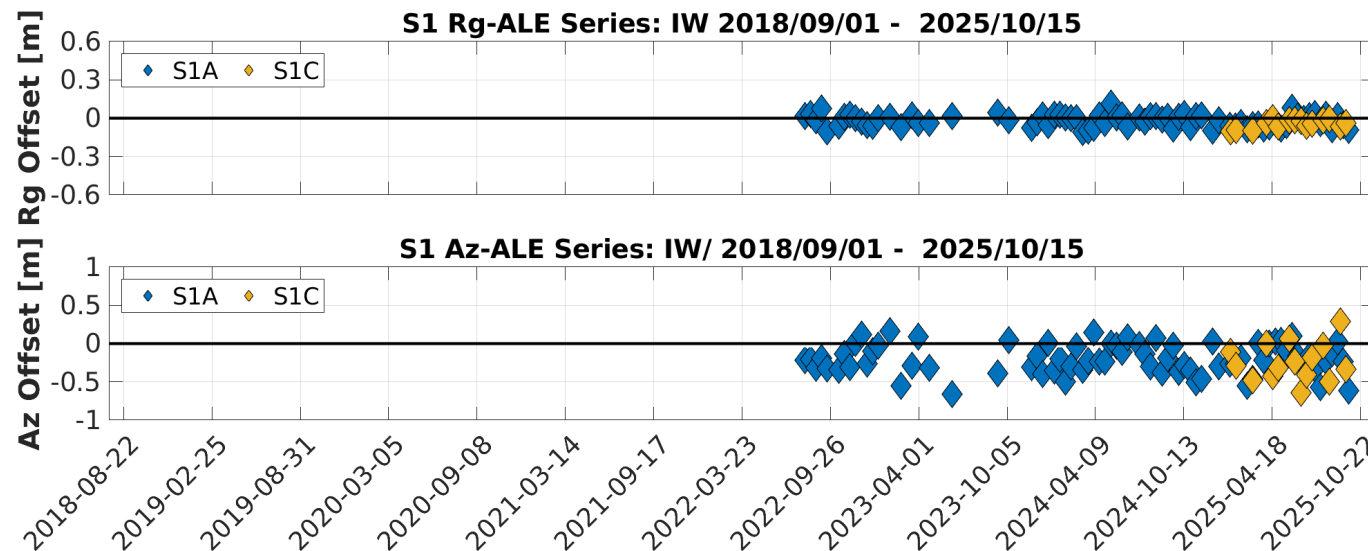
- ❖ Interferometric Wide-swath data
- ❖ Rg/Az: 3 x 22m @ 250 x ... km

	Rg ALE [m]	Az ALE [m]
S1	-0.024 ± 0.047	-0.208 ± 0.204
S1A	-0.020 ± 0.048	-0.202 ± 0.196
S1C	-0.045 ± 0.034	-0.239 ± 0.247



### SAR image versus CR reference positions:

- ❖ Atmosph. path delay corrections
  - ❖ Solid Earth deformations
  - ❖ Sensor calibration constants
  - ❖ S-1 SAR system corrections
- Range / Azimuth residuals
- Statistical outliers removed



# Sentinel-1 SAR sensor geometric validation

Analysis, results provided by Christoph Gisinger, DLR



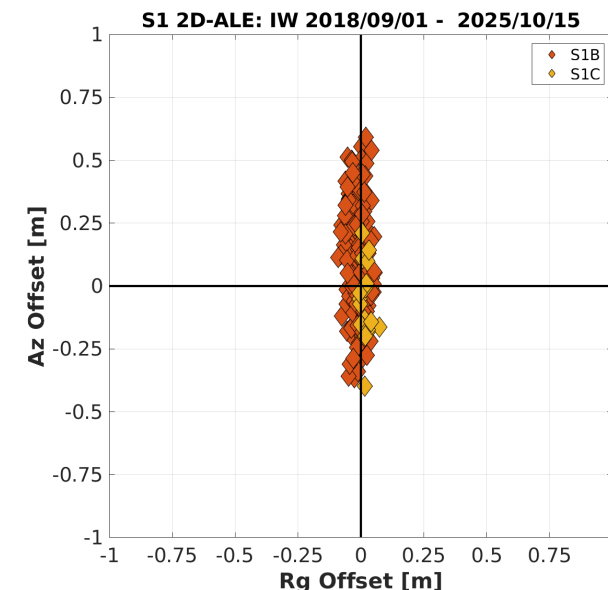
## Yarragadee Geodetic Station



## CR - DESC

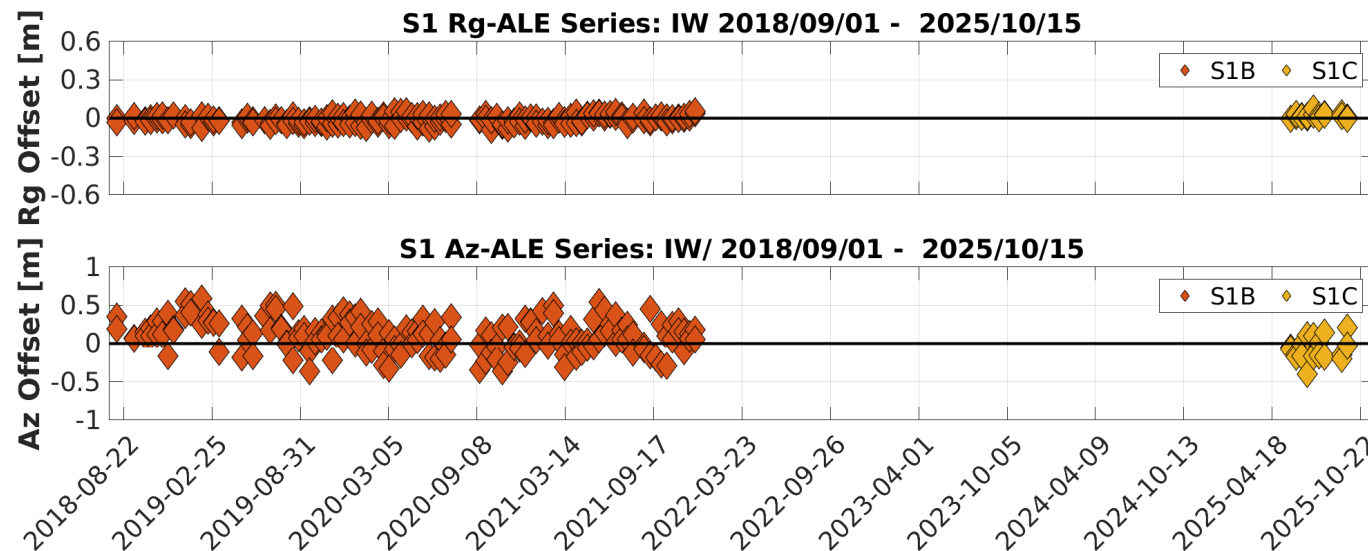
- ❖ Interferometric Wide-swath data
- ❖ Rg/Az: 3 x 22m @ 250 x ... km

	Rg ALE [m]	Az ALE [m]
S1	$-0.008 \pm 0.032$	$0.091 \pm 0.211$
S1B	$-0.011 \pm 0.032$	$0.108 \pm 0.209$
S1C	$0.018 \pm 0.020$	$-0.072 \pm 0.149$



## SAR image versus CR reference positions:

- ❖ Atmosph. path delay corrections
  - ❖ Solid Earth deformations
  - ❖ Sensor calibration constants
  - ❖ S-1 SAR system corrections
- Range / Azimuth residuals
- Statistical outliers removed





# Pinnacles, Western Australia

Site supporting Landsat Next Calibration



Contact PI: [Cindy.Ong@csiro.au](mailto:Cindy.Ong@csiro.au)

## Proposed for inclusion as part of RadCalNet



- ❖ Being developed by CSIRO to be part of RADCALNET
- ❖ CE 318-TU12 BRDF Sun Photometer
- ❖ Gill GMX600 Weather Station
- ❖ Kipp and Zonen CMP3 Pyranometer
- ❖ Raspberry Pi
- ❖ Sky camera with fisheye lens
- ❖ HYPSTAR-SR (Planned 2026)



# Googong, New South Wales

Site supporting Landsat Next Calibration



DION pontoon in the Googong Reservoir

Contact PI: [Janet.Anstee@csiro.au](mailto:Janet.Anstee@csiro.au)

## Dark-water Inland Observatory Network (DION)

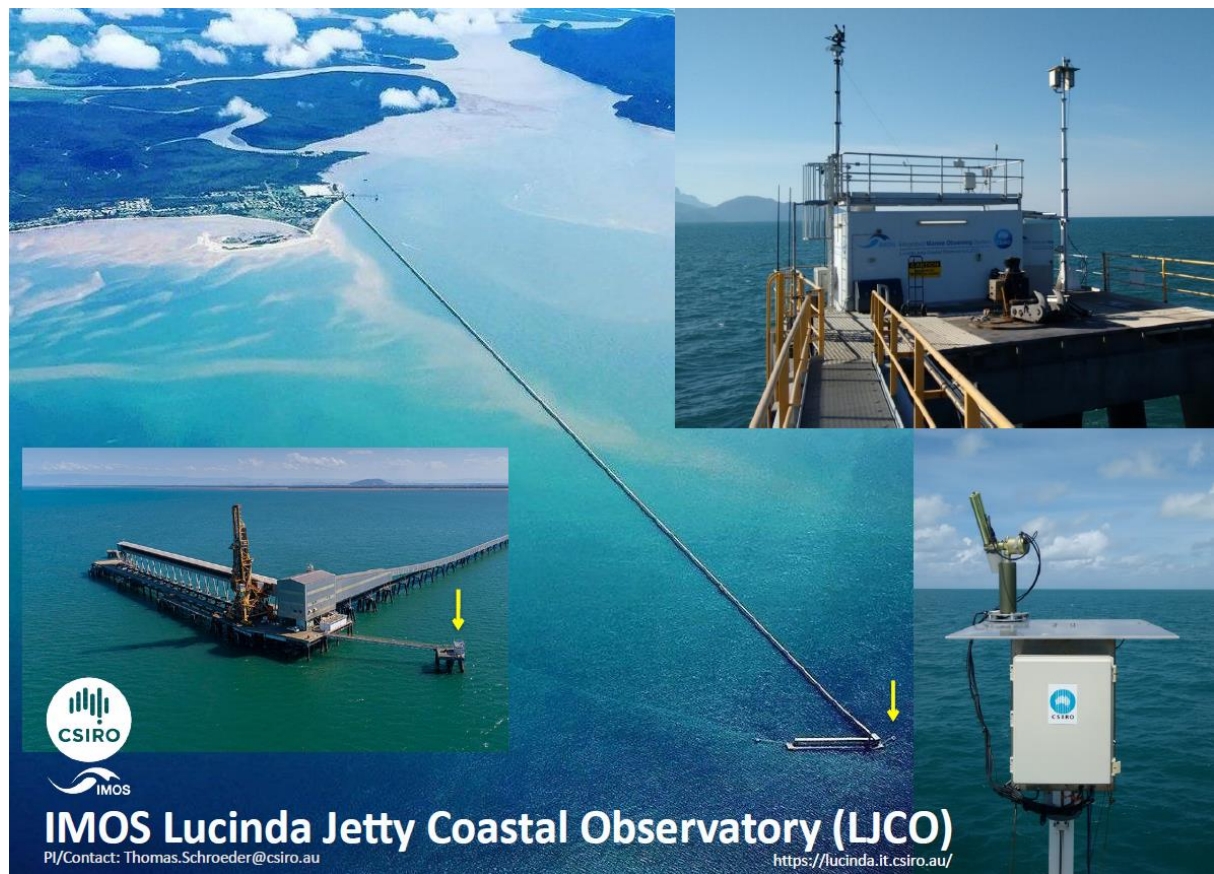


- ❖ 3 x TRIOS Ramses Hyperspectral Radiometers (Ed, Lw, Lsky)
- ❖ Weather Station (temp, humidity, pressure, dew point, wind speed)
- ❖ Thermistor Chain (temp at surface and 1-8 m)
- ❖ 2 x Heitronics Thermal Radiometers
- ❖ Webcams (water, sky)
- ❖ Water quality sensors - YSI EXO2
- ❖ Kurloo GPS Instrument (water surface height)



# Lucinda, Queensland

Site supporting Landsat Next Calibration



Contact PI: Thomas.Schroeder@csiro.au

## Lucinda Jetty Coastal Observatory (LJCO)



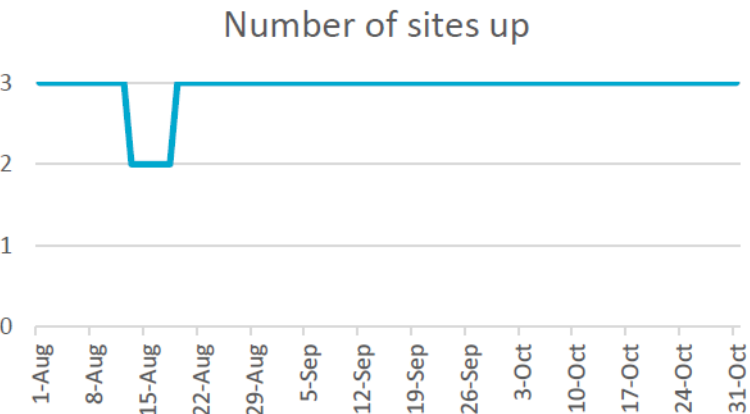
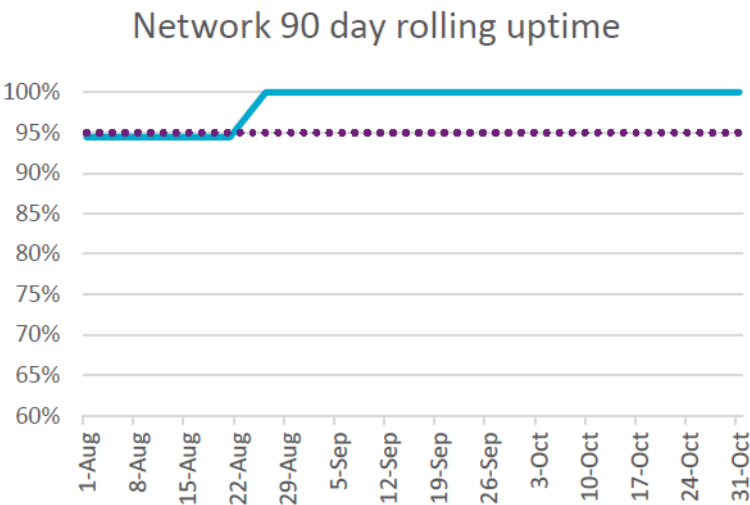
- ❖ Satlantic HyperOCR  
Radiometer on solar tracker
- ❖ CIMEL CE318-T SeaPrism  
Radiometer
- ❖ WetStar Fluorometer
- ❖ Weather Station
- ❖ ACs, WQM, BB9, EcoTriplet
- ❖ Webcams (Sky & Sea)
- ❖ HYPSTAR-SR (Planned 2026)



# Calibration network performance reporting

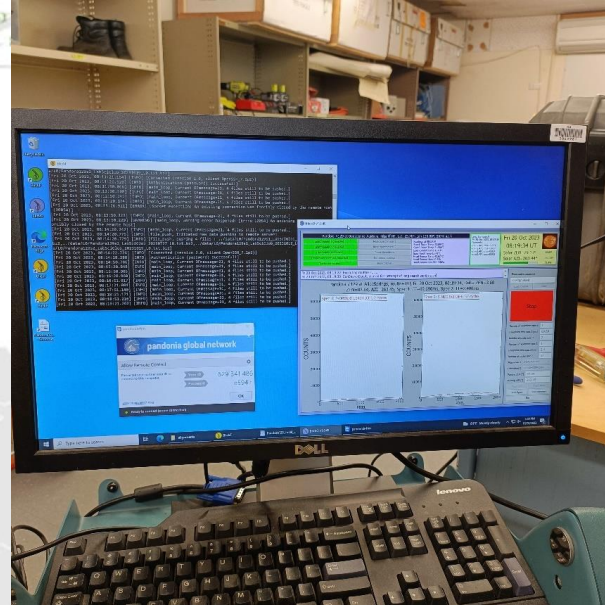
Performance Measure	PIAU	LICO	DION
Measurement standard/protocol alignment	RadCalNet in progress	FRM4SOC in progress	FRM4SOC in progress
Data standard alignment	RadCalNet in progress	FRM4SOC in progress	FRM4SOC in progress
Public data availability	RadCalNet in progress	IMOS AODN LICO Portal	In progress
Open site or equipment issues	0	1	0
Site up time (over 90 days) on 31 Oct	100%	100%	93%
Network up time (over 90 days) on 31 Oct	100%		

Risks, Issues, Concerns	Mitigation	Impact rating
Site access to LICO remains limited due to works on the jetty and gangway leading to the observatory. This means limited ability to respond to any issues that might occur.	As this is outside of CSIRO control, little mitigation is possible	Medium





# Pandora instrument at Alice Springs



- ❖ Pandora #129 at Alice Springs is part of the Pandonia global network supporting reference measurements for atmospheric composition
- ❖ Geoscience Australia has supported the operation of the Pandora at Alice Springs since 2018 (FRM4AQ)



## PANDONIA GLOBAL NETWORK

Reference Measurements of Atmospheric Composition

# Summary

- ❖ The QCRA with 40 CRs spread over 130km x 130km area, deployed in 2014 continues to support SAR calibration of several missions.
- ❖ The QCRA conforms to FRM4SAR protocols and routinely used by the Sentinel-1 MPC team, it has demonstrated excellent performance over the last 10 years and continues to maintain performance standards.
- ❖ The 2018 survey of QCRA provides precise coordinates for the CR Apex Point at the 40 sites and are available through the SARCalNet database.
- ❖ The two CRs at the Yarragadee fundamental geodetic station have been surveyed in 2025, preliminary results confirm stability of coordinates, geometric calibration performance verified by Sentinel-1 MPC and DLR teams. Expected to be made available through SARCalNet soon.
- ❖ Three instrumented calibration sites in Australia will provide operational support for the Landsat Next mission.
- ❖ The Pandora instrument at Alice Springs, as part of the global Pandonia network, continues to be supported as an FRM4AQ.



**Australian Government**  
**Geoscience Australia**

## Further information

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