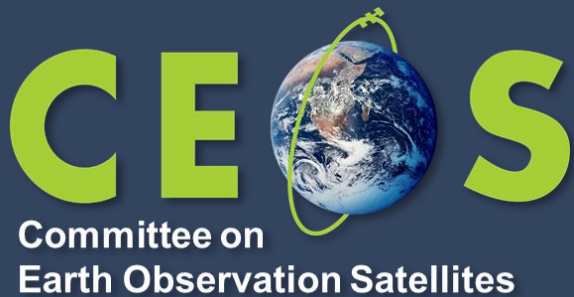
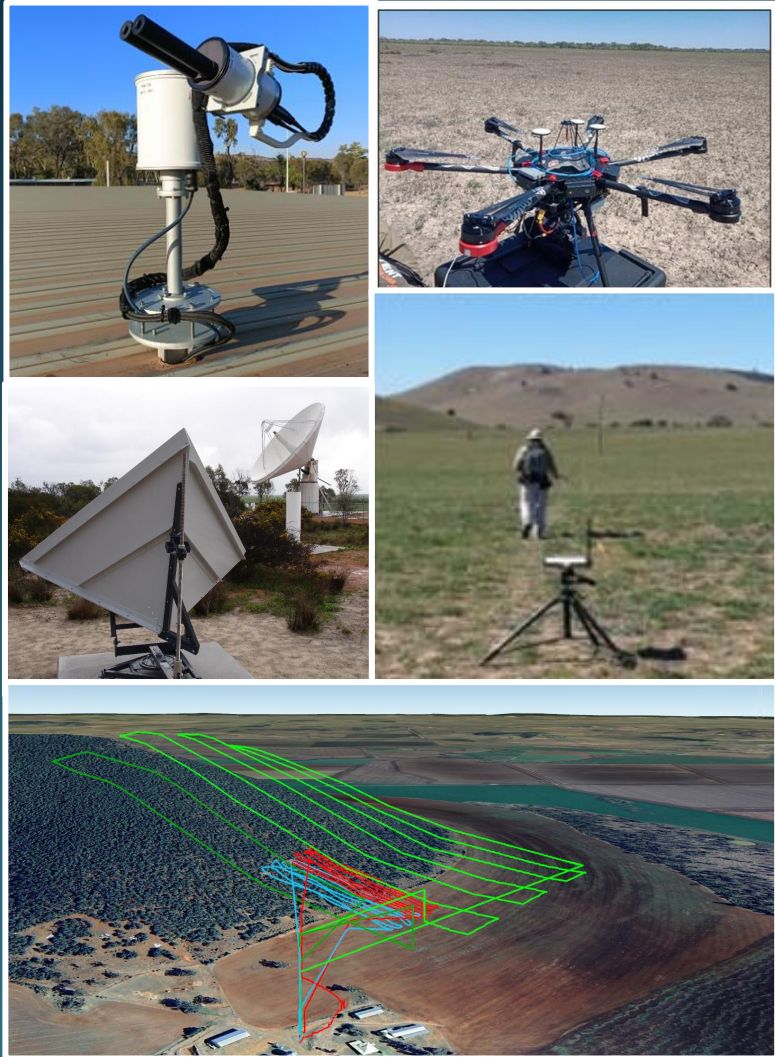


# Geoscience Australia Update



**Medhavy Thankappan,  
Geoscience Australia  
Agenda Item B.4  
WGISS / WGCV Joint Meeting  
15 & 18 October 2024  
Sioux Falls, South Dakota, USA**



# GA Calibration Validation and Data Quality Update

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**Medhavy Thankappan**

**Director, Data Processing, Quality and Integrity**

**Satellite Land Imaging Collection Branch**

**Space Division**

# Geoscience Australia

- **Australian Government (part of Industry Science Energy and Resources Portfolio)**
- **Australia's national geoscience organisation**
- **650+ staff, mostly based in Canberra**
- **Satellite Ground Station Facility in Alice Springs**



**Chief Executive Officer  
Dr James Johnson**

<b>Office of the Chief Scientist</b>	<b>Minerals, Energy and Groundwater Division</b>	<b>Space Division</b>	<b>Place and Communities Division</b>	<b>Corporate Division</b>
<b>Chief Scientist</b> Dr Steve Hill	<b>Chief of Division</b> Dr Andrew Heap	<b>Chief of Division</b> Alison Rose	<b>Chief of Division</b> Maree Wilson	<b>Chief of Division</b> Trent Rawlings
	<b>Basin Systems</b> Dr David Robinson	<b>Positioning Australia</b> Dr Martine Woolf	<b>Oceans, Reefs, Coasts and the Antarctic</b> Dr Jodie Smith	<b>Enterprise Data and Digital</b> Clive Rossiter
	<b>Mineral Systems</b> Marina Costelloe	<b>Satellite Land Imaging</b> Dr David Hudson	<b>National Location Information</b> Lisa Bush	<b>Enabling Services</b> Erika Taturan
	<b>Advice, Investment Attraction and Analysis</b> Kristina Anastasi	<b>Digital Earth</b> Leyla Alpaslan	<b>Community Safety</b> Dr John Dawson	<b>Organisational Investment</b> Mike Olive

# National space-based geoscience leadership

## Earth Observation

Digital images of the Earth's surface compiled from spectral data collected by sensors carried on satellites.

## Position, Navigation and Timing

Accurate and precise determination of location and orientation three-dimensionally from global navigation satellite systems.

## Geodesy

Accurate measurement of the shape, orientation and gravity field of the Earth and how it changes over time.

**Delivering earth observations and precise positioning to enable a sustainable environment, resilient society and strong economy**



# Landsat Next Partnership

## What is it?

- A full value chain partnership to ensure the full benefits of Landsat and Landsat Next are realised by Australians, Americans and the Indo-Pacific
- Backed by \$AUD448.7 million of new investment by the Australian Government to FY2034-45 and then ~\$AUD43.2m per year ongoing
- Backed by billions of dollars of U.S. Government investment

## What will it achieve?

Guaranteed right to use current and future Landsat data

Any purpose; All users in Indo-Pac

Streamlined access to data fit for Australia and region

Collect and downlink priority

Deeper First Nations science, skills and tech partnerships

New science, analytics and technology that drive impact

Including towards the National Science and Research Priorities

Platform for Indo-Pacific engagement

Including commercial and scientific partnerships

Opportunities for the Alice Springs region

More sustainable Landsat program

Investment in Australian capability



The Hon Madeleine King MP, Minister for Resources and Northern Australia and Dr David Applegate, Director of USGS Mar 2024 in Washington, D.C.



Allison Rose, Chief of Space Division, Geoscience Australia and Darcee Killpack, a/g Associate Director of USGS Aug 2024 in Washington, D.C.



Senator the Hon Penny Wong, Minister for Foreign Affairs, and Antony Blinken, US Secretary of State. Aug 2024 in Washington DC

# Landsat Next Partnership: Key elements

Enhanced Alice Springs  
Ground Station  
Capability  
Ka/X/S-band, highly  
redundant

Permanent operational  
instrumented cal/val  
facilities  
2 in Aus, 1 in Pacific

Indo-Pacific Regional  
Data Hub  
Landsat, Sentinel and other  
high-quality trusted data

Operational Data  
Quality and Integrity  
Monitoring Facility  
Foreign government and  
commercial missions

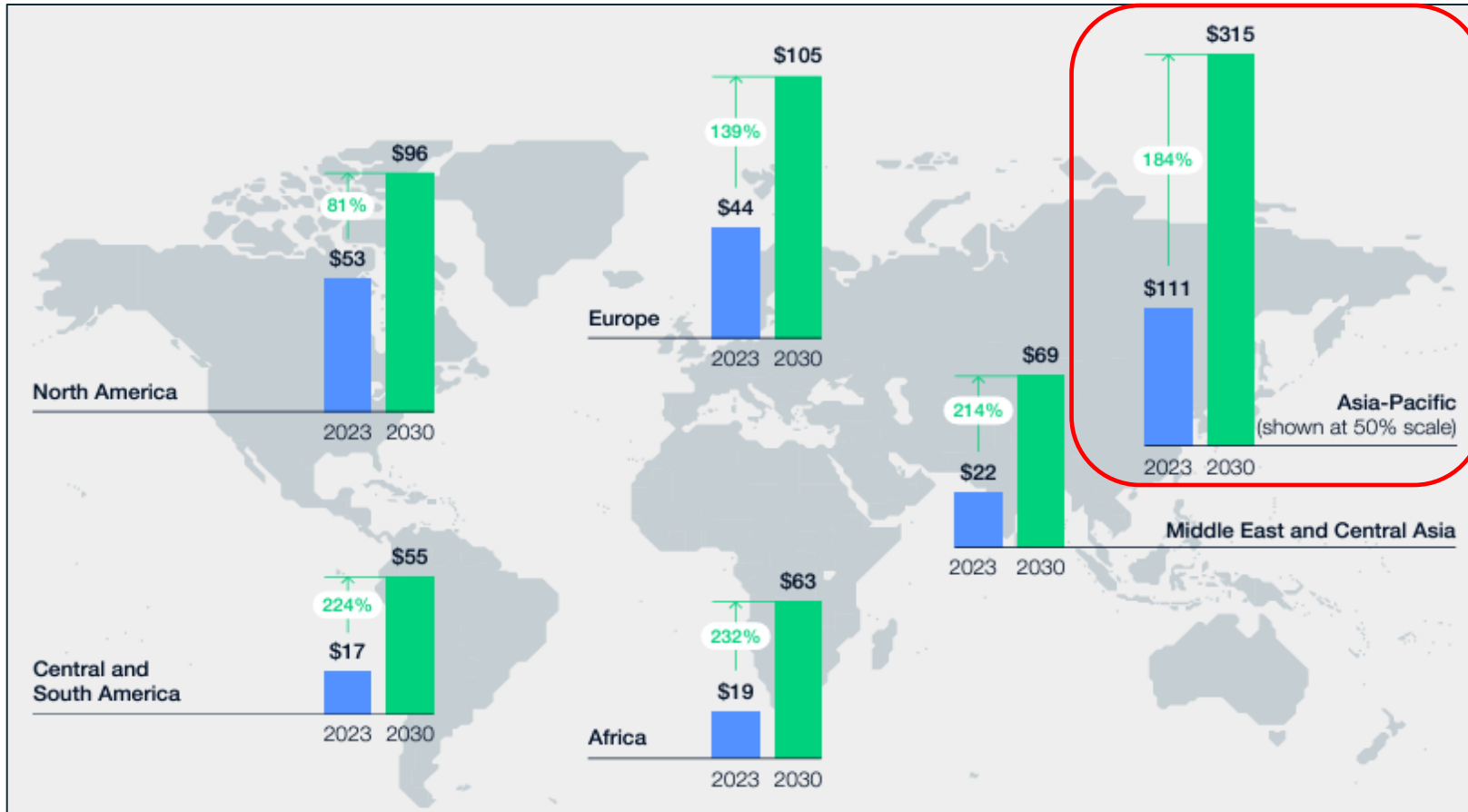
First Nations Technical  
Training and Research  
Programs  
Including ground station skills

New, open, science and  
next-generation  
analytics technology  
Including AI

Field data collection  
programs  
Training and validation data

Interoperability  
engagement and uplift  
Including through CEOS

# Earth Observation Data - Value Creation Potential



- ❖ Value creation results from **analysis and application** of EO data.

- ❖ From 2023 to 2030, future growth in **North America and Europe** projected to be **steady**.

- ❖ The **Asia Pacific** region projected to capture the **largest share of value with a potential of \$315 billion**.

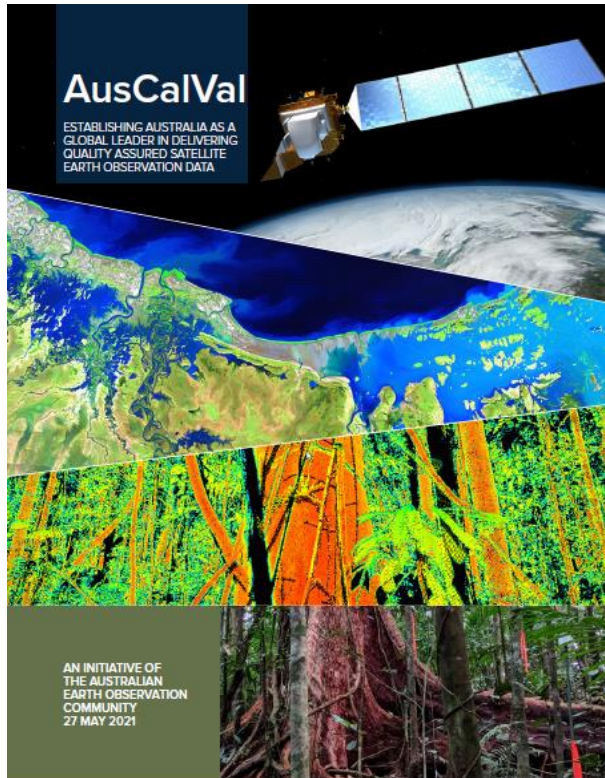


Source: Amplifying the Global Value of Earth Observation - Insight Report (May 2024)



# Quality Assurance Trust and Consistency

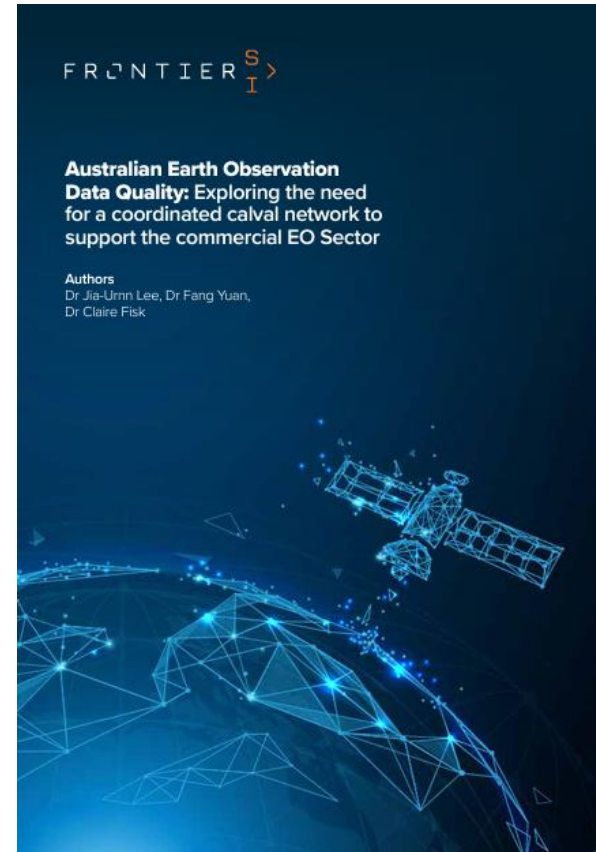
Quality, consistency, and trust in Earth observation data have been recurrent themes in recent studies of the sector.



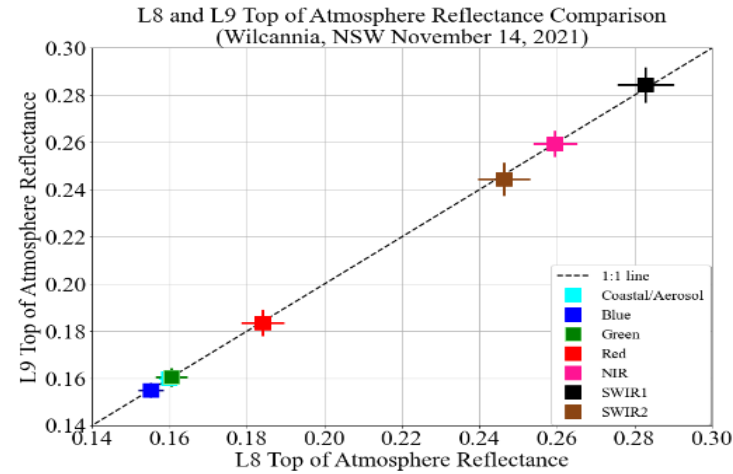
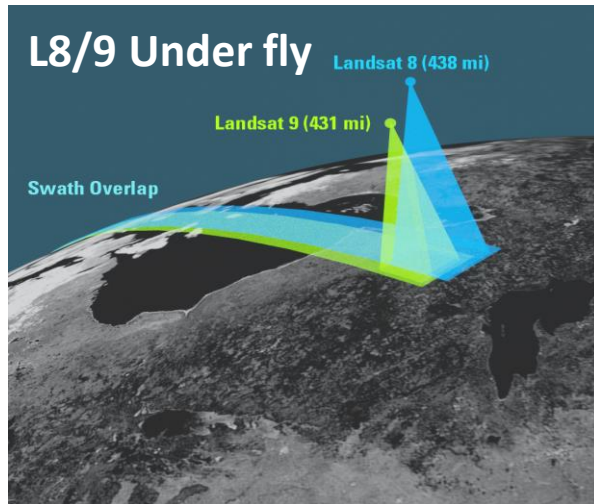
EOA Earth Observation Australia FRONTIER S I > SMARTSAT Cooperative Research Centre



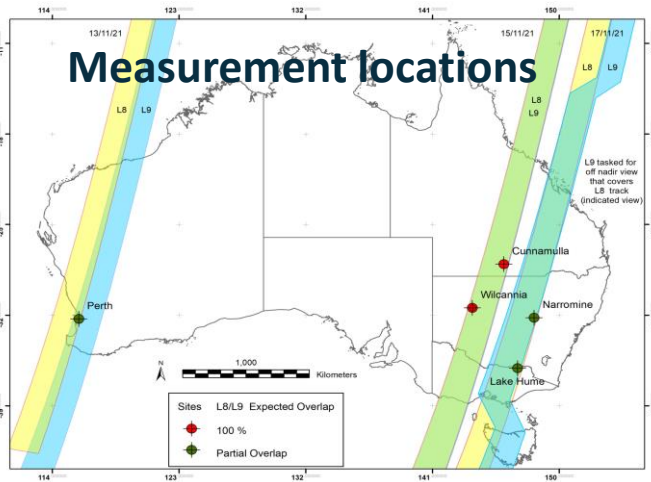
Report by the Australian Centre for Space Governance  
April 2024  
www.spacegovcentre.org



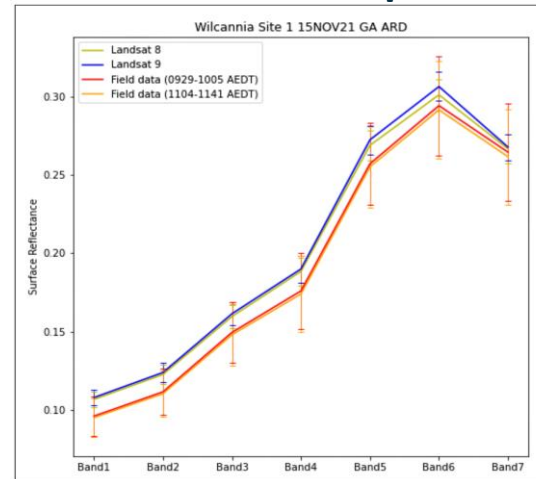
# Coincident satellite overpasses: Landsat 8 / 9 under fly campaign



Drone based measurements



## Data match-up



Byrne, G.; Broomhall, M.; Walsh, A.J.; Thankappan, M.; Hay, E.; Li, F.; McAtee, B.; Garcia, R.; Anstee, J.; Kerrisk, G.; et al. Validating Digital Earth Australia NBART for the Landsat 9 Underfly of Landsat 8. Remote Sens. 2024, 16, 1233. <https://doi.org/10.3390/rs16071233>

# Alternative approach to field data collection for SR validation

- Our continental SR validation campaigns relied on teams undertaking field measurements over specific sites at the time of satellite overpass. We still use fixed sites to test equipment and protocols, while this approach has advantages, we have been exploring other approaches.
- With two Landsat satellites (8/9) and two Sentinel-2 satellites (A/B), there are areas where the Landsat and Sentinel-2 swaths overlap.

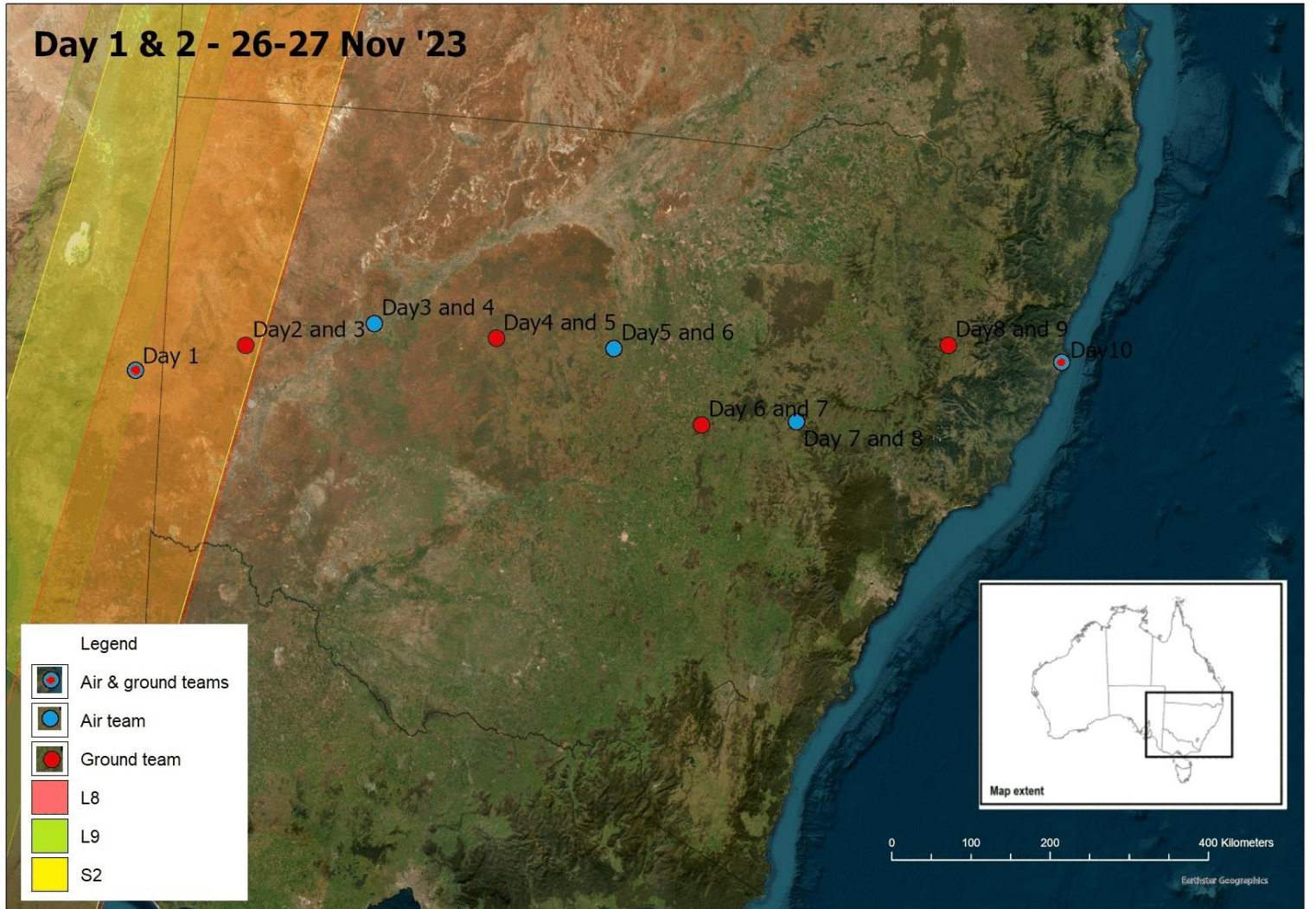
Landsat 8 / 9

Sentinel-2 A / B



# Validation transects in satellite overlap areas

- Overlap zones are around 50km for Landsat and 60km for Sentinel-2 in central NSW, up to 24 matchups are possible in a 10-day period.
- A campaign in June/July yielded 11 matchups, weather and technical issues restricted capture of the full 24 possible match-ups.
- Increasingly, we use teams to collect data across these overlap zones along transects to get the most out of field validation data collection.



# National Spectral Database

- Access to the field data from the National Spectral Database

<https://knowledge.dea.ga.gov.au/data/product/australian-national-spectral-database/>

The screenshot displays the National Spectral Database web interface. The browser address bar shows the URL: [knowledge.dea.ga.gov.au/validation/daily-report/2023-11-27/](https://knowledge.dea.ga.gov.au/validation/daily-report/2023-11-27/). The page header includes the Australian Government Geoscience Australia and Digital Earth AUSTRALIA logos, along with navigation links for Data Products, User Guides, DEA Notebooks, Alerts & Changelog, and More. A search bar is located in the top right corner.

The main content area is titled "Daily" and lists "Daily reports". The selected report is for "2023-11-27: Transect NSW Site 1, Sentinel-2B overpass". Other reports listed include "2023-11-26: Transect South Australia Site 1, Landsat 8 overpass", "2023-09-22: Mullion, Landsat 8 overpass", "2023-07-25: Mullion, Sentinel-2A overpass", "2023-05-09: Mullion, Landsat 9 overpass", "2023-04-22: Mullion, Sentinel-2B overpass", and "2023-01-17: Mullion, Landsat 9 overpass".

Under "User guides", there is a link to "Learn how to analyse the reports".

The report content is divided into three columns:

- Left Column:** A satellite imagery tile of true colour (RGB) surface reflectance. It covers an area of approximately 2 km × 2 km. A white box indicates the size and location of the field site. The axes are labeled "Longitude" and "Latitude".
- Middle Column:** A band-by-band plot of surface reflectance for satellite and field data. The x-axis is "Band Number" (1 to 12) and the y-axis is "Surface Reflectance" (0.1 to 0.4). The plot shows "Sentinel-2B" (blue line) and "Field" (red line) data with error bars.
- Right Column:** A plot of Satellite Surface Reflectance versus Field Site Surface Reflectance. The x-axis is "Field Site Surface Reflectance" and the y-axis is "Satellite Surface Reflectance", both ranging from 0.0 to 0.8. The plot shows "Median error" (black dots), "Coastal Aerosol" (blue triangle), "Blue" (green square), "Green" (red circle), "Red" (magenta diamond), "Red Edge 1" (cyan plus), "Red Edge 2" (orange cross), "Red Edge 3" (yellow asterisk), "NIR 1" (purple square), "NIR 2" (pink triangle), "SWIR 2" (dark green diamond), and "SWIR 3" (black star). A solid blue line represents the one-to-one equality between field and satellite measurements. The legend includes: Median error, Coastal Aerosol, Blue, Green, Red, Red Edge 1, Red Edge 2, Red Edge 3, NIR 1, NIR 2, SWIR 2, SWIR 3. The bottom-right corner of the plot contains the following statistics:  $R^2$  coefficient = 0.992, slope = 1.002, intercept = 0.002, standard error = 0.007.

# New capability for field spectroscopy



Manual field spectroscopy



UAV based field spectroscopy.

Advantages

- Can be deployed over almost any surface
- Repeatable measurements
- Configurable measurement protocols

Article

# Validating Digital Earth Australia NBART for the Landsat 9 Underfly of Landsat 8

Guy Byrne <sup>1,\*</sup>, Mark Broomhall <sup>1</sup>, Andrew J. Walsh <sup>1</sup>, Medhavy Thankappan <sup>1</sup>, Eric Hay <sup>1</sup>, Fuqin Li <sup>1</sup>, Brendon McAtee <sup>2</sup>, Rodrigo Garcia <sup>3</sup>, Janet Anstee <sup>4</sup>, Gemma Kerrisk <sup>5</sup>, Nathan Drayson <sup>5</sup>, Jason Barnetson <sup>6</sup>, Ian Samford <sup>6</sup> and Robert Denham <sup>7</sup>

- <sup>1</sup> Geoscience Australia, Cnr Jerrabomberra Ave. and Hindmarsh Drive, Symonston, ACT 2609, Australia; mark.broomhall@ga.gov.au (M.B.); andrew.walsh@ga.gov.au (A.J.W.); medhavy.thankappan@ga.gov.au (M.T.); eric.hay@anu.edu.au (E.H.); fuqin.li@ga.gov.au (F.L.)
- <sup>2</sup> Remote Sensing and Satellite Research Group, School of Earth & Planetary Sciences, Curtin University, GPO Box U1987, Perth, WA 6845, Australia; bkmcaatee@gmail.com
- <sup>3</sup> School of Earth Sciences, University of Western Australia, Perth, WA 6009, Australia; rodrigo.garcia@uwa.edu.au
- <sup>4</sup> AquaWatch Australia CSIRO Space and Astronomy, Canberra, ACT 2601, Australia; janet.anstee@csiro.au
- <sup>5</sup> CSIRO Environment, GPO Box 1700, Canberra, ACT 2601, Australia; gemma.kerrisk@csiro.au (G.K.); nathan.drayson@csiro.au (N.D.)
- <sup>6</sup> Queensland Department of Environment and Science, GPO Box 2454, Brisbane, QLD 4001, Australia; jason.barnetson@des.qld.gov.au (J.B.); ian.samford@des.qld.gov.au (I.S.)
- <sup>7</sup> School of the Environment, University of Queensland, Brisbane, QLD 4072, Australia; rob.denham@des.qld.gov.au
- \* Correspondence: guy.byrne@ga.gov.au; Tel.: +61-2-6249-9646



**Citation:** Byrne, G.; Broomhall, M.; Walsh, A.J.; Thankappan, M.; Hay, E.; Li, F.; McAtee, B.; Garcia, R.; Anstee, J.; Kerrisk, G.; et al. Validating Digital Earth Australia NBART for the Landsat 9 Underfly of Landsat 8. *Remote Sens.* **2024**, *16*, 1233. <https://doi.org/10.3390/rs16071233>

Academic Editors: Cody Anderson, Lawrence Ong, Michael Choate, Esad Micijevic and Kathryn Ruslander

Received: 9 February 2024  
 Revised: 13 March 2024  
 Accepted: 18 March 2024  
 Published: 31 March 2024



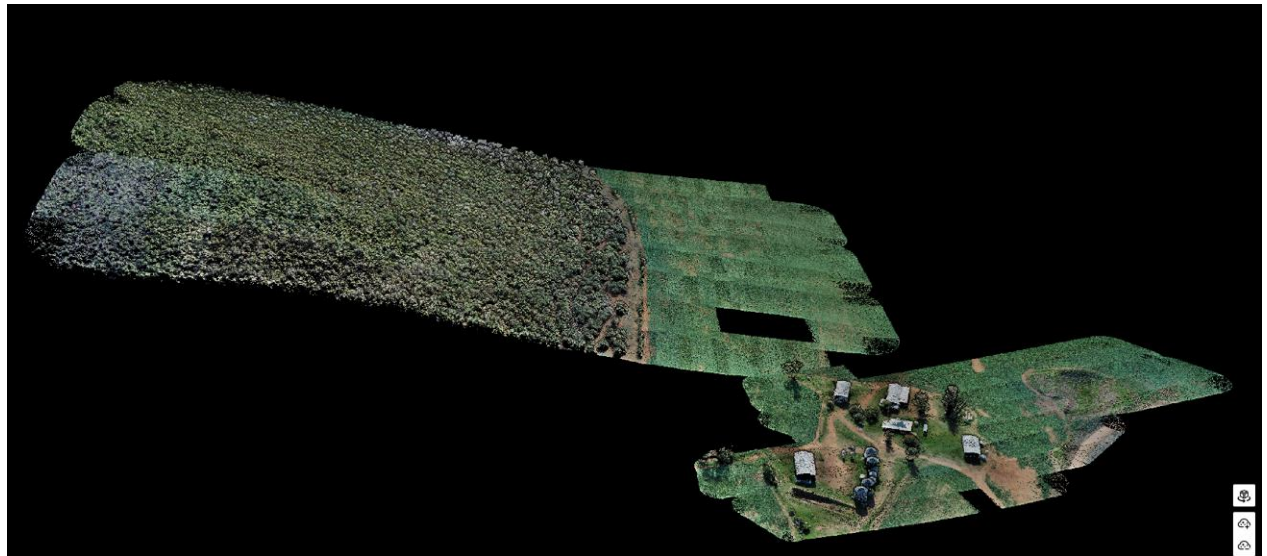
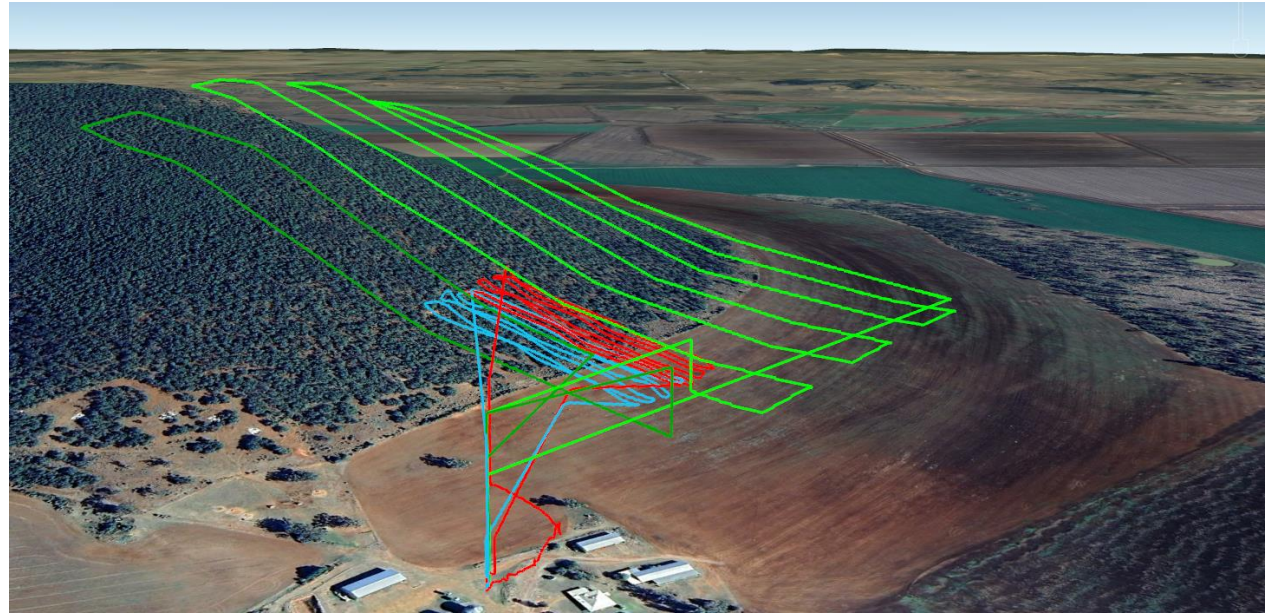
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**Abstract:** In recent years, Geoscience Australia has undertaken a successful continental-scale validation program, targeting Landsat and Sentinel analysis-ready data surface reflectance products. The field validation model used for this program was successfully built upon earlier studies, and the measurement uncertainties associated with these protocols have been quantified and published. As a consequence, the Australian earth observation community was well-prepared to respond to the United States Geological Survey (USGS) call for collaborators with the 2021 Landsat 8 (L8) and Landsat 9 (L9) underfly. Despite a number of challenges, seven validation datasets were captured across five sites. As there was only a single 100% overlap transit across Australia, and the country was amidst a strong La Niña climate cycle, it was decided to deploy teams to the two available overpasses with only 15% side lap. The validation sites encompassed rangelands, chenopod shrublands, and a large inland lake. Apart from instrument problems at one site, good weather enabled the capture of high-quality field data allowing for meaningful comparisons between the radiometric performance of L8 and L9, as well as the USGS and Australian Landsat analysis-ready data processing models. Duplicate (cross-calibration) spectral sampling at different sites provides evidence of the field protocol reliability, while the off-nadir view of L9 over the water site has been used to better compare the performance of different water and atmospheric correction processing models.

**Keywords:** Landsat 8; Landsat 9; surface reflectance; validation; underfly

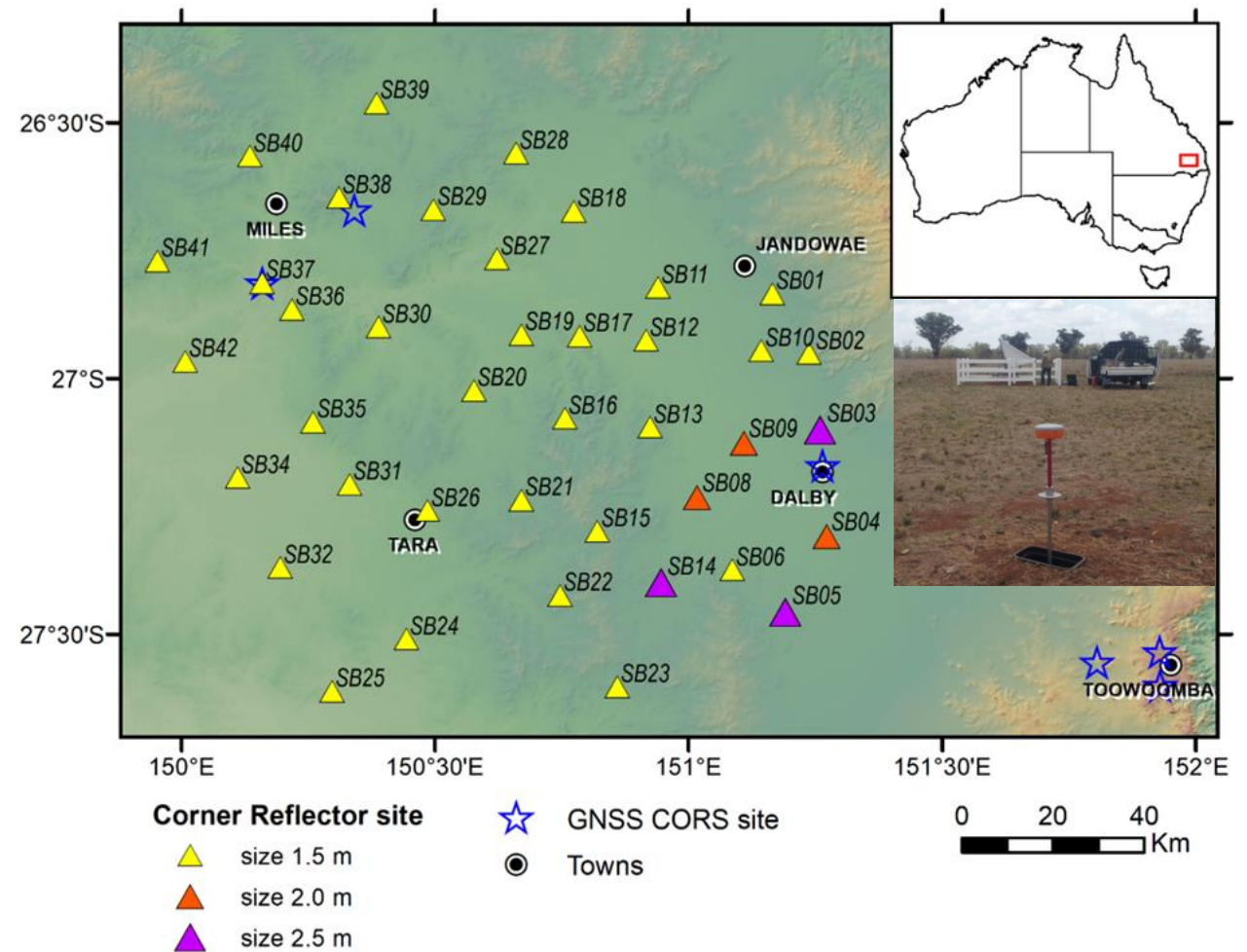
## 1. Introduction

How appropriate a particular dataset is and which validation framework is best are essential questions in earth observation (EO) science [1]. The Committee on Earth Observation Satellites (CEOS) Quality Assurance Framework for Earth Observation (QA4EO) states that ‘Data and derived products shall have associated with them an indicator of quality to enable users to assess their suitability for particular applications, i.e., their ‘fitness for purpose’ [2]. The framework also suggests that ‘comparisons are an essential tool within any quality assurance (QA) framework as they provide a source of unequivocal information



# Queensland Corner Reflector Array (QCRA) - Support for FRM4SAR

- Geoscience Australia operates the QCRA, 40 CRs spread over 100km x 100km in South-east Queensland, Australia
- Enables consistency in the quality of SAR data from multiple sensors, and will be a key contribution to the SARCaINet initiative
- The QCRA has supported calibration of several SAR missions including Sentinel-1 since 2014





# Permanent SAR corner reflectors at Yarragadee

- Yarragadee is one of the few fundamental geodetic co-location stations in the world.
- One ascending and one descending trihedral CRs (1.5m), permanently installed in August 2018
- Permanent Yarragadee CR coordinates independently verified by TSX 3D SAR solution, results within 2 cm



CR at Yarragadee Geodetic Observatory

# Pandora – Support for FRM4AQ



- 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)

PGN status

official non official

real time  

delayed  



## PANDONIA GLOBAL NETWORK

Reference Measurements of Atmospheric Composition

# Harmonised CEOS GCP Database

**remote sensing** **MDPI**

Article  
**Bundle Adjustment Using Space-Based Triangulation Method for Improving the Landsat Global Ground Reference**

James C. Storey <sup>1,†</sup>, Rajagopal Ranganjan <sup>1,\*</sup> and Michael J. Choate <sup>2</sup>

<sup>1</sup> KBR, Contractor to the U.S. Geological Survey, Earth Resources Observation and Science Center, Sioux Falls, SD 57105, USA  
<sup>2</sup> U.S. Geological Survey, Earth Resources Observation and Science Center, Sioux Falls, SD 57105, USA  
\* Correspondence: ranganjan@contractor.usgs.gov; Tel.: +1 605 414 4620

Received: 23 May 2019; Accepted: 6 July 2019; Published: 19 July 2019

**Abstract:** There is an ever-increasing interest and need for accurate georegistration of remotely sensed data products to a common global geometric reference. Although georegistration has improved substantially in the last decade, the lack of an accurate global ground reference dataset poses serious issues for data providers seeking to make geometrically stackable analysis-ready data. The existing Global Land Survey 2009 (GLS2009) dataset derived from Landsat 7 images provides global coverage and can be used as a reference dataset, but its accuracy is much lower than what can be attained using the agile and precise pointing capability of the new spacecrafts. The improved position and pointing knowledge of the new spacecrafts such as Landsat 8 can be used to improve the accuracy of the existing global ground control points using a space-based triangulation method. This paper discusses the theoretical basis, formulation, and application of the space-based triangulation method at a continental scale to improve the accuracy of the GLS-derived ground control points. Our triangulation method involves adjusting the spacecraft position, velocity, attitude, altitude, rate, and ground control point locations, iteratively, by linearizing the non-linear viewing geometry, such that the residual errors in the measured image points are minimized. The complexity of the numerical iteration and processing is dealt with in our approach by processing and eliminating the ground points one at a time. This helps to reduce the size of the normal matrix significantly, thereby making the triangulation of a continent-wide scale block feasible and efficient. One of the unique characteristics of our method is the use of a correlation model linking the attitude corrections between images of the same pass, which promotes consistency in the attitude corrections. We evaluated the performance of our triangulation method over the Australian continent using the Australian Geographic Reference Image (AGRI) dataset as a reference. Both a free adjustment, using only the pointing information of the Landsat 8 spacecraft, and a constrained adjustment using the AGRI as external control were performed and the results compared. The Australian block's horizontal accuracy improved from 15.4 m to 3.6 m with the use of AGRI controls and from 15.4 m to 8.8 m without the use of AGRI controls.

**Keywords:** triangulation; bundle adjustment; Landsat; Sentinel; geometric reference; GLS2009; ground control; geometric correction

**1. Introduction**

With the recent advancements in remote sensing and data processing technologies, there has been a substantial increase in the use of medium- and high-resolution satellite data to monitor and assess the changes in the global landscape. The scientific users of today have access to more data

Remote Sens. 2019, 11, 1640; doi:10.3390/rs11101640 www.mdpi.com/journal/remotesensing

**esa** Reference: S2-MPC\_PHB\_GCP\_L1B\_L1C\_GRI  
Issue: V3  
Date: 2023-07-07

**SENTINEL 2**

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## S2 MPC

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**Copernicus  
Sentinel-2 GRI as  
Database of GCPs  
in L1B & L1C -  
Product Handbook**

Ref. S2-MPC\_PHB\_GCP\_L1B\_L1C\_GRI

**CS**  
Copernicus Sentinel

**GG** **IGN**

**GEOSCIENCE AUSTRALIA**


Australian Government  
Geoscience Australia

## AGRI: The Australian Geographic Reference Image

A TECHNICAL REPORT

Dr Adam Lewis, Lei-Wi Wang, Rohan Coghlan

GeoCat #  
72657



APPLYING GEOSCIENCE TO AUSTRALIA'S MOST IMPORTANT CHALLENGES

# SRIX4VEG - Support for FRM4VEG

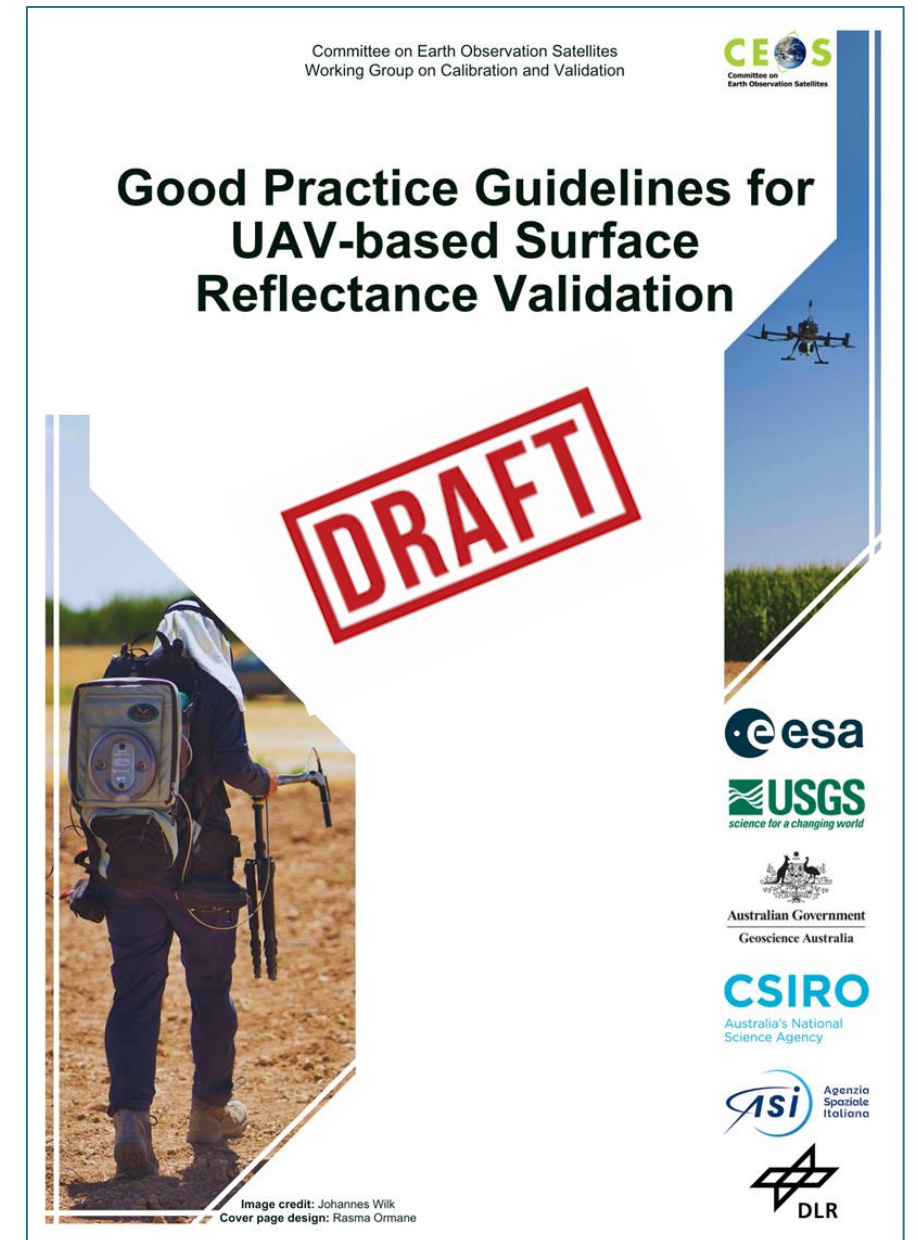
Surface Reflectance Intercomparison for Vegetation (SRIX4VEG)

SRIX4VEG Workshop 2 at ESRI, Frascati (23-24 Nov 2023)

- GA and CSIRO supported the SRIX4VEG campaigns on UAV-based protocols for validation of surface reflectance products
- SRIX4VEG II field campaign was in Australia (March 2024)



fiducial reference  
measurements  
for vegetation



# Concept of a Satellite Cross-calibration Radiometer (SCR)



Article

## Concept of a Satellite Cross-Calibration Radiometer for In-Orbit Calibration of Commercial Optical Satellites

Medhavy Thankappan, Jon Christopherson, Simon Cantrell, Robert Ryan, Mary Pagnutti, Courtney Bright, Denis Naughton, Kathryn Ruslander, Lan-Wei Wang, David Hudson et al.

### Special Issue

Space-Borne Earth Observation Data for Monitoring Natural and Anthropogenic Phenomena: A Look towards Climate Change and Advanced Processing Methods

Edited by  
Dr. Marco Polcarì, Dr. Letizia Anderlini and Dr. Antonio Montuori

<https://www.mdpi.com/2746708>



<https://doi.org/10.3390/rs16081333>



Article

## Concept of a Satellite Cross-Calibration Radiometer for In-Orbit Calibration of Commercial Optical Satellites

Medhavy Thankappan <sup>1,\*</sup>, Jon Christopherson <sup>2</sup>, Simon Cantrell <sup>2</sup>, Robert Ryan <sup>3</sup>, Mary Pagnutti <sup>3</sup>, Courtney Bright <sup>4</sup>, Denis Naughton <sup>1</sup>, Kathryn Ruslander <sup>2</sup>, Lan-Wei Wang <sup>1</sup>, David Hudson <sup>1</sup>, Jerad Shaw <sup>2</sup>, Shankar Nag Ramasari Chandra <sup>2</sup> and Cody Anderson <sup>5</sup>

- <sup>1</sup> Geoscience Australia, Symonston, ACT 2609, Australia
  - <sup>2</sup> KBR Inc., Earth Resources Observation and Science Center, Sioux Falls, SD 57198, USA
  - <sup>3</sup> Innovative Imaging and Research Inc., Stennis Space Center, MS 39529, USA
  - <sup>4</sup> CSIRO, Canberra, ACT 2601, Australia
  - <sup>5</sup> United States Geological Survey, Earth Resources Observation and Science Center, Sioux Falls, SD 57198, USA
- \* Correspondence: medhavythankappan@ga.gov.au; Tel: +61-2-6249-9310

**Abstract:** The satellite Earth observation (EO) sector is burgeoning with hundreds of commercial satellites being launched each year, delivering a rich source of data that could be exploited for societal benefit. Data streams from the growing number of commercial satellites are of variable quality, limiting the potential for their combined use in science applications that need long time-series data from multiple sources. The quality of calibration performed on optical sensors onboard many satellite systems is highly variable due to calibration methods, sensor design, mission objective, budget, or other operational constraints. A small number of currently operating well-characterised satellite systems with onboard calibration, such as Landsat-8/9 and Sentinel-2, and planned future missions, like the NASA Climate Absolute Radiance and Refractivity Observatory (CLARREO) Pathfinder, the European Space Agency (ESA)'s Traceable Radiometry Underpinning Terrestrial and Helio Studies (TRUTHS), and LIBRA from China, are considered benchmarks for optical data quality due to their traceability to international measurement standards. This paper describes the concept of a space-based transfer calibration radiometer called the Satellite Cross-Calibration Radiometer (SCR) that would enable the calibration parameters from satellites such as Landsat-8/9, Sentinel-2, or other benchmark systems to be transferred to a range of commercial optical EO satellite systems while in orbit. A description of the key characteristics of the SCR to successfully operate in orbit and transfer calibration from reference systems to client systems is presented. A system like the SCR in orbit could complement SI-Traceable satellites (SITSats) to improve data quality and consistency and facilitate the interoperable use of data from multiple optical sensor systems for delivering higher returns on the global investment in EO.

**Keywords:** cross-calibration; hyperspectral; multi-sensor interoperability; radiometric calibration

### 1. Introduction

The number of Earth observation (EO) missions is growing rapidly, generating ever-increasing volumes of satellite data with immense potential for global applications across multiple science domains. Sustainable access to quality EO data from multiple satellite systems is fundamental for many environmental monitoring programs ranging in scale from regional to global. The ability to use data interoperably from multiple satellite systems from both the civil and commercial sectors enhances the frequency of observations for time-series applications where transient events could be missed due to fewer opportunities for observation by a single system. Scientists often use multiple optical remote sensing sensor systems to obtain datasets for their research, which makes it necessary to comprehend how differences between the datasets can affect the results for various scientific purposes. In



**Citation:** Thankappan, M.; Christopherson, J.; Cantrell, S.; Ryan, R.; Pagnutti, M.; Bright, C.; Naughton, D.; Ruslander, K.; Wang, L.-W.; Hudson, D.; et al. Concept of a Satellite Cross-Calibration Radiometer for In-Orbit Calibration of Commercial Optical Satellites. *Remote Sens.* **2024**, *16*, 1333. <https://doi.org/10.3390/rs16081333>

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*Remote Sens.* **2024**, *16*, 1333. <https://doi.org/10.3390/rs16081333>

<https://www.mdpi.com/journal/remotesensing>





Australian Government  
Geoscience Australia

# Thank you

**Further information**

[medhavy.thankappan@ga.gov.au](mailto:medhavy.thankappan@ga.gov.au)

