Confidential

YU-NSI Cal/Val Site

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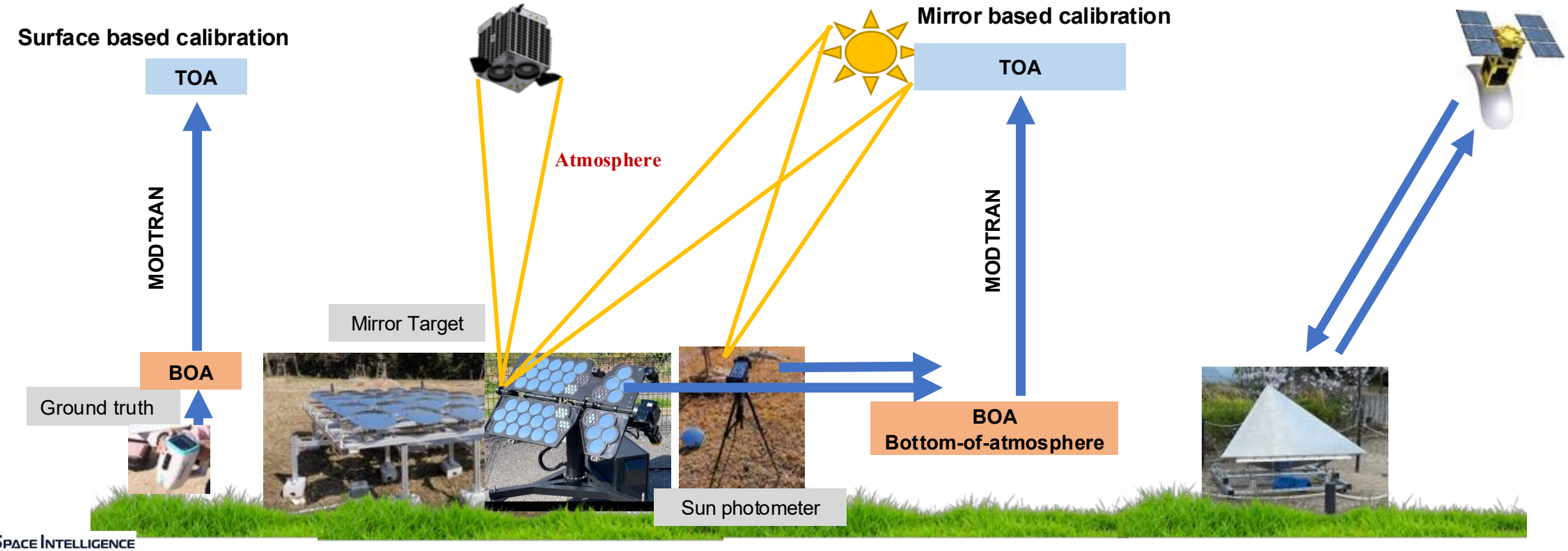
The first “Start-up” to conduct Calibration as a Service (CaaS) for satellites

Conceptual framework of NSI Cal/Val Site

- **Optical** satellite data calibration sites based on
  - Surface reflectance measurements
  - Ground point, fixed and automated source-mirror reflectors
- **SAR** satellite data calibration based on
  - Corner reflector

Data calibration
Harmonization
Multi-data utilization

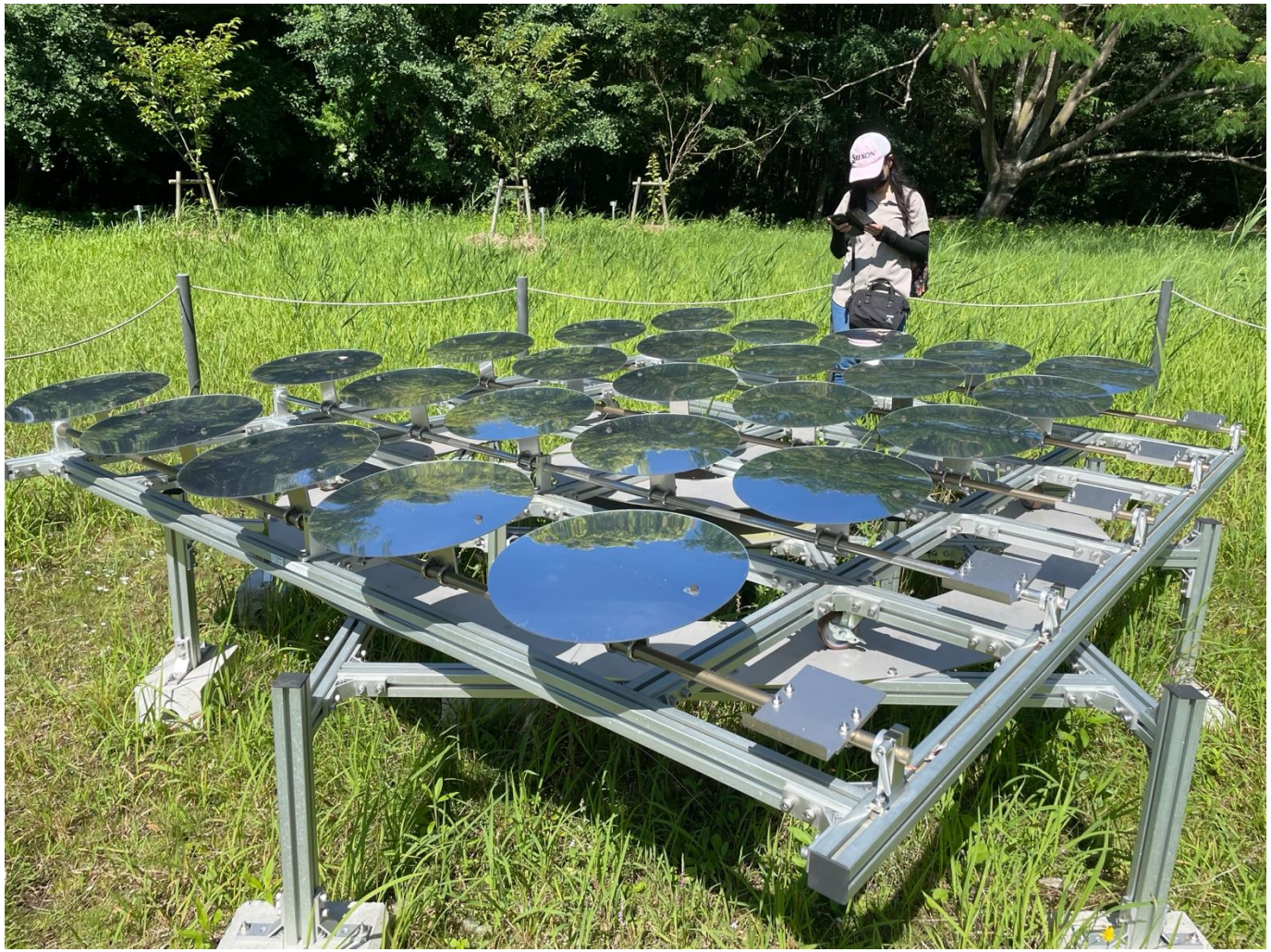


*Joint research with Yamaguchi University, Japan

Optical Data

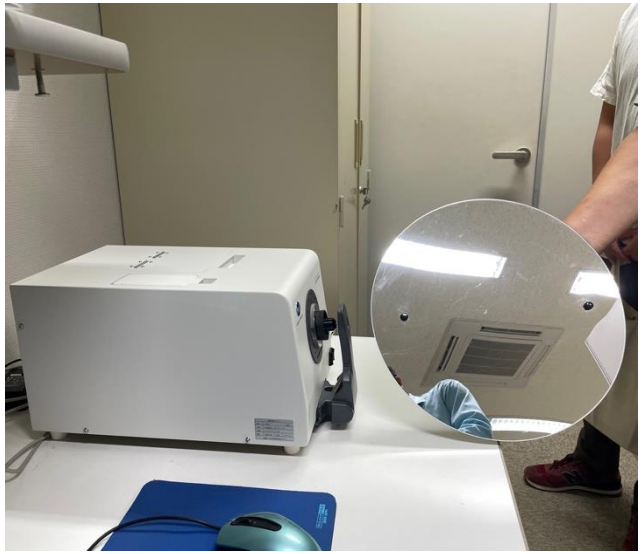
Large fixed Mirror Array (Tokiwa site)

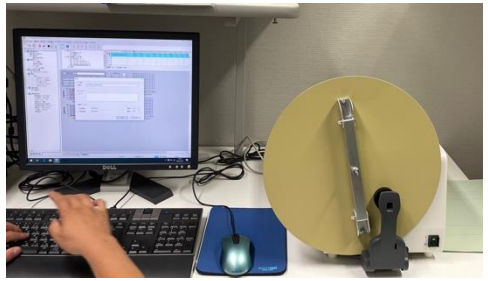
- Established in March 2021, Yamaguchi University
- With an aim to use this site as add-on to the vicarious calibration site. Requires less man power, due to the known surface reflectance.
- The total Lambertian Equivalent Reflectance (LER) can be controlled by keeping some mirror in different offset.

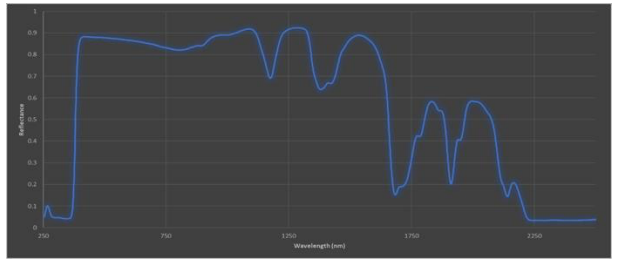


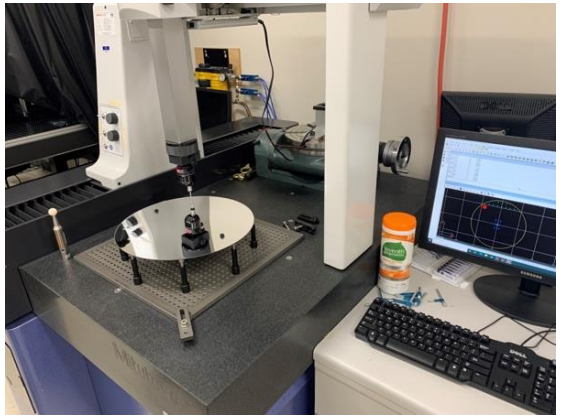
Mirror reflectance measurement in the lab

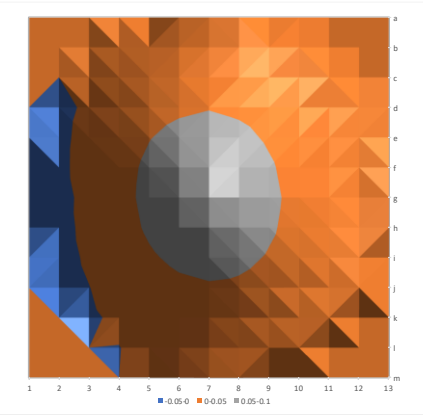
- Mirror reflectivity measured in the lab in Japan and at Labsphere, USA.
- The measured range was in between the visual range i.e. 350 to 750 nm in Japan and in USA the range was till 2000 nm.
- We have reconfirmed the condition of the mirrors' reflectivity after use of three years and found that the reflectivity changes are still within 2% range.











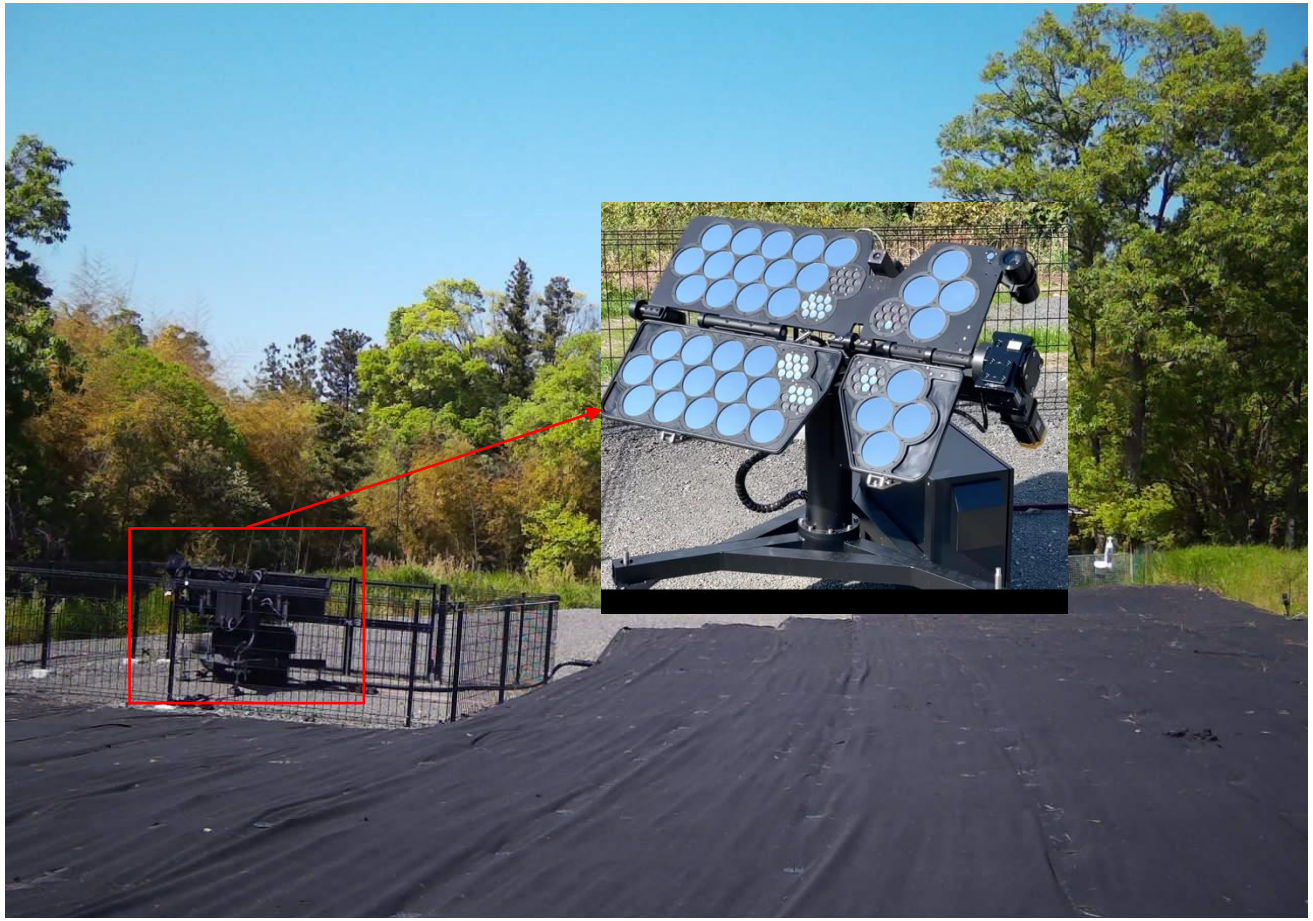
NSI Mirror site

1st installation for calibration **outside the U.S.**

Labsphere

NSI New Space Intelligence

NSI Mirror site



NSI Mirror site

Mirror Array in Satellite Imageries

Mirror-array In
panchromatic band

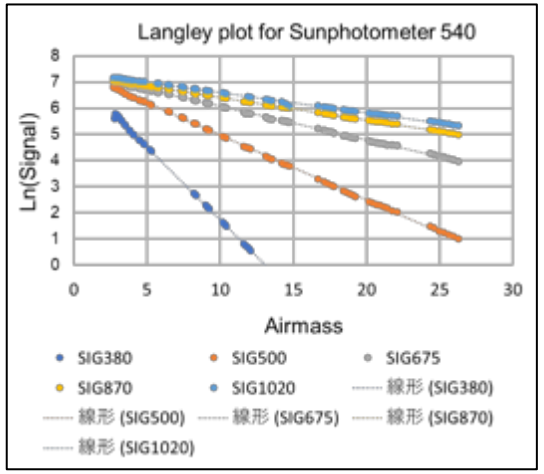
Mirror-array In True Colour
Image (TCI)

Atmospheric Measurements

- Atmospheric measurements by Sunphotometer and Ozonemeter (Aerosol optical thickness, precipitable water vapor column, total ozone column etc.)
  - MICROTOPS II 540 and MICROTOPS II 521 (Solar light Corp. USA)

a) b) c)

Microtops II for atmospheric measurement
a) Model 521, b) Model 540, c) Measurement for aerosol, ozone and water vapor depth at calibration site “Kirara” of Yamaguchi



Langley plot. for Model 521 and 540 Microtops measurement

Band name	Langley plot line	The extraterrestrial constant Vo
380nm	y = -0.5593x + 7.3151	7.3151
500nm	y = -0.2476x + 7.4444	7.4444
675nm	y = -0.1289x + 7.3609	7.3609
870nm	y = -0.0871x + 7.2867	7.2867
1020nm	y = -0.0775x + 7.3733	7.3733

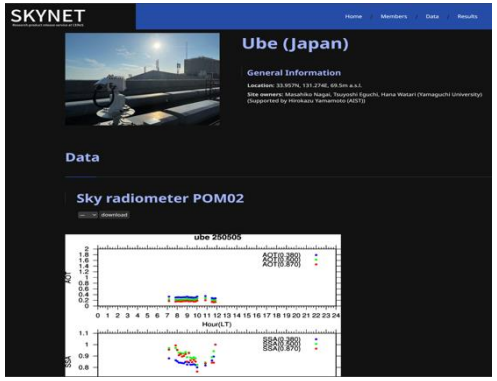
Table of the estimated extraterrestrial constant Vo for Model 521’s bands.

Estimation of the extraterrestrial constant Vo through Langley method

Atmospheric Measurements, YU

Skyradiometer POM-02

Sky camera

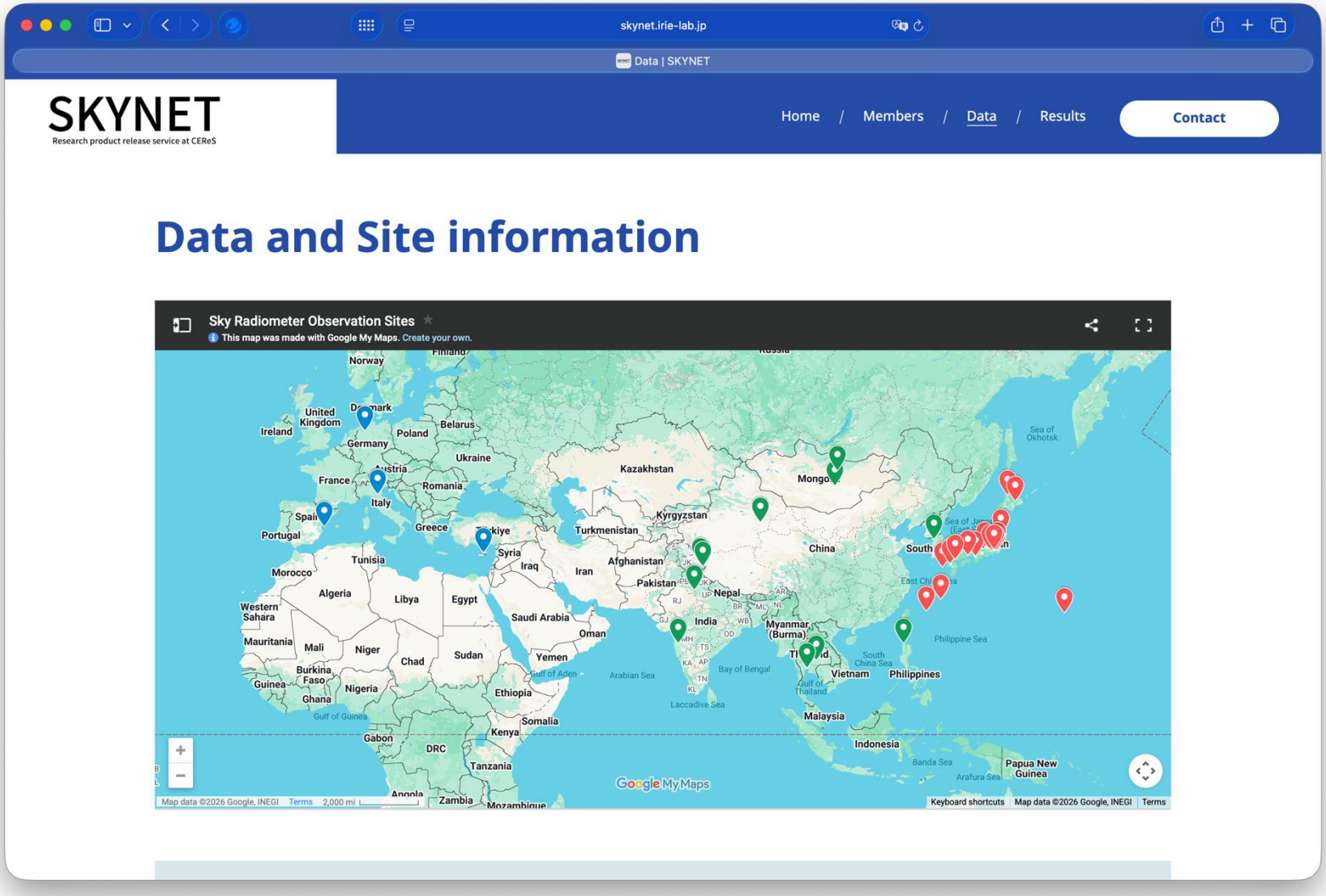


Data access

Azimuth scan (aerosol observation)
Observes the amount of scattered solar radiation in the surrounding area. Observations are made once every 10 minutes.

Direct light observation
Observes the amount of direct solar radiation from the sun. Observations are made once every 3 minutes.

Atmospheric Measurements, YU



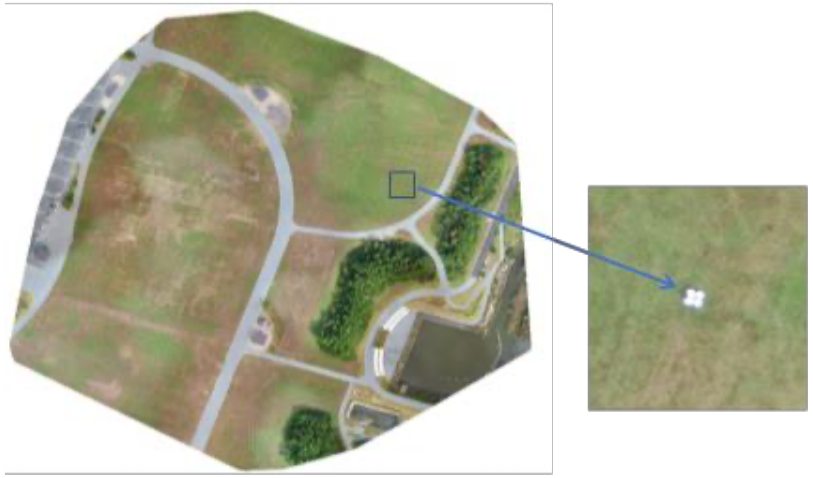
Calibration field campaigns

ASD HandHeld 2

ASD FieldSpec 4

SVC HR-512i

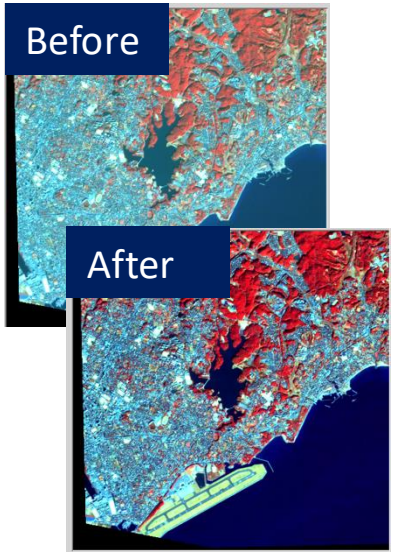
Microtops II 540, 521



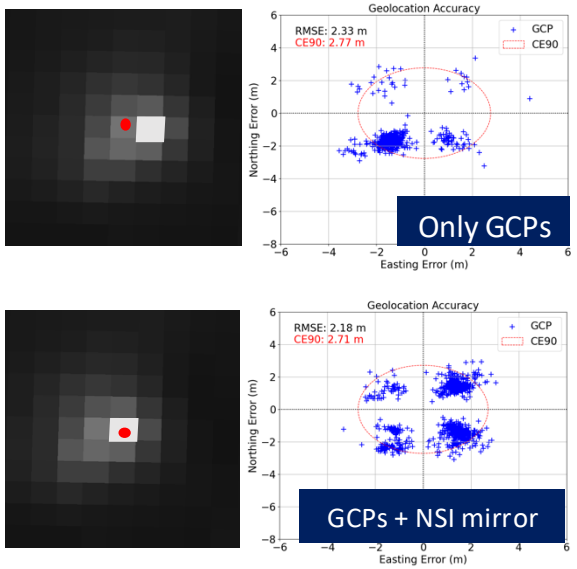
UAV Observation

Calibration as a Service (CaaS) pipeline

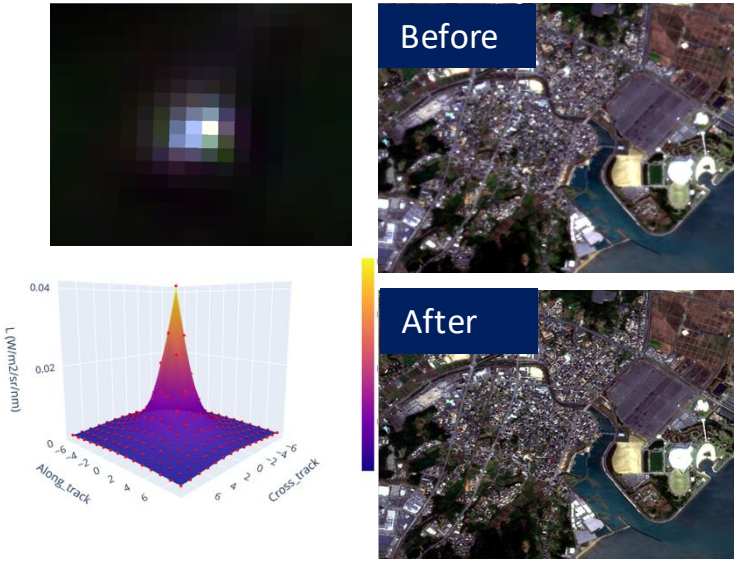
Satellite, Sun and Mirror geometry setting and alignment



Radiometric Calibration & Atmospheric correction



Geometric Correction

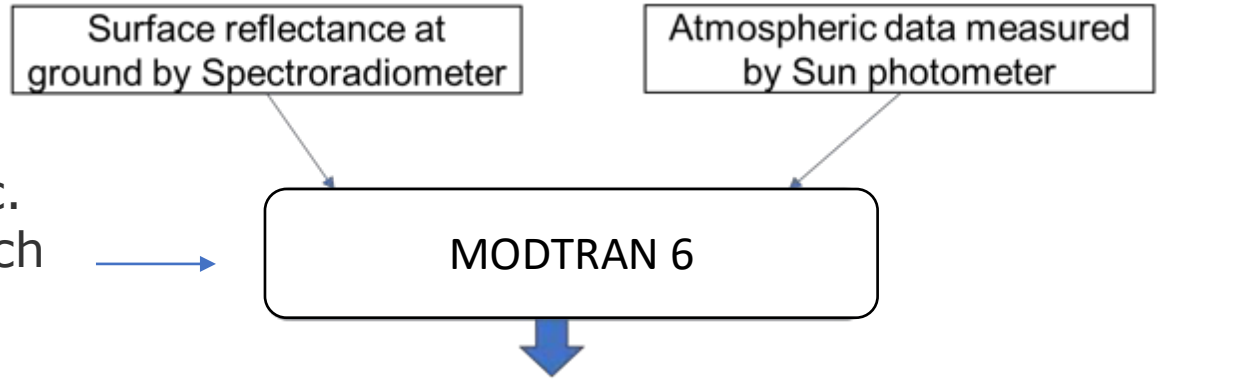


IPSF Correction or Deblurring of the image

Automated Pipeline generating ARD

Estimation of TOA radiance using MODTRAN-6

Spectral Sciences, Inc. and Air Force Research Laboratory (USA)

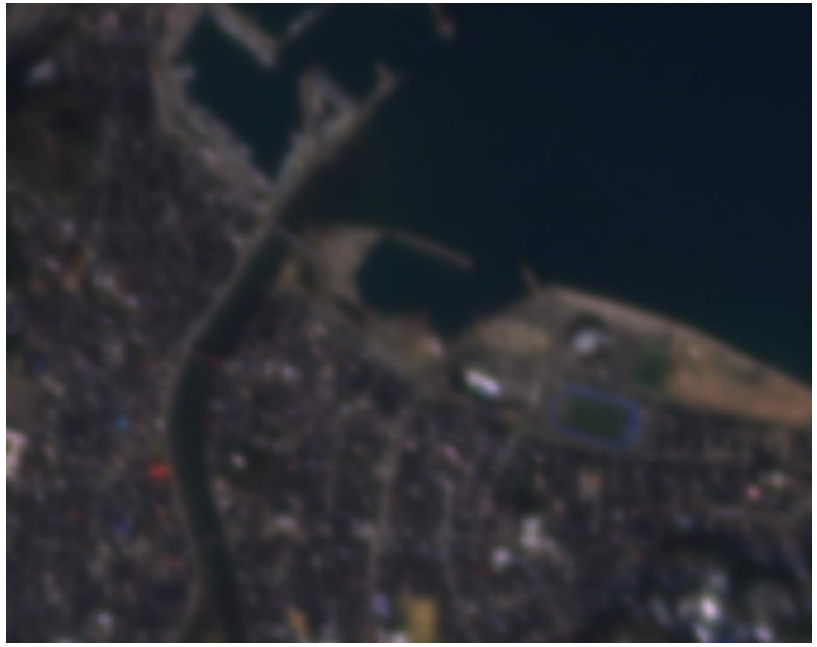


Satellite radiance

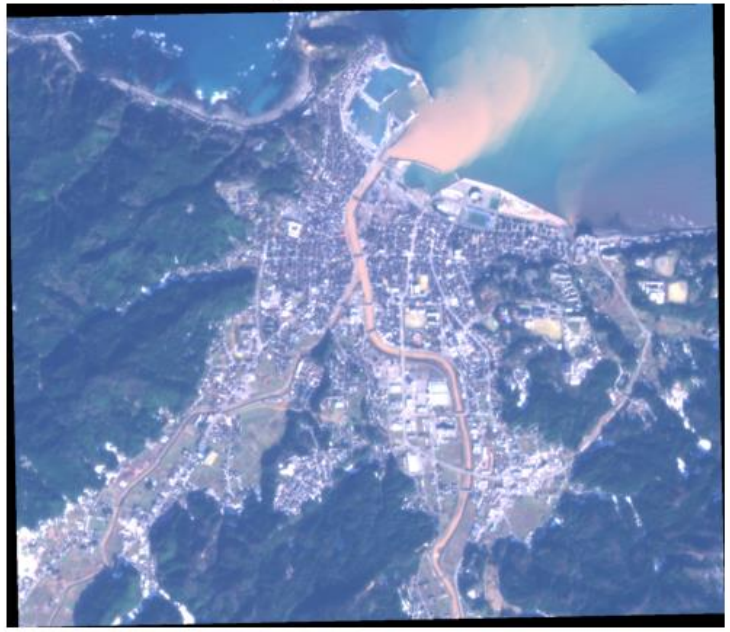
	Band 1	Band 2	Band 3	Band 4	Band 5
Satellite pixel values	6.354 %	5.991 %	3.395 %	7.686 %	11.659 %
Modtran Simulated values	6.349 %	5.912 %	3.746 %	7.811 %	11.793 %
Difference (Satellite - Modtran)	0.005	0.079	-0.351	-0.125	-0.134
Difference (%) (Difference/ Modtran)	0.077%	1.338%	-9.372%	-1.604%	-1.133%

Before Disaster (w/o Atmospheric Correction)

Before Disaster (w/ Atmospheric Correction)



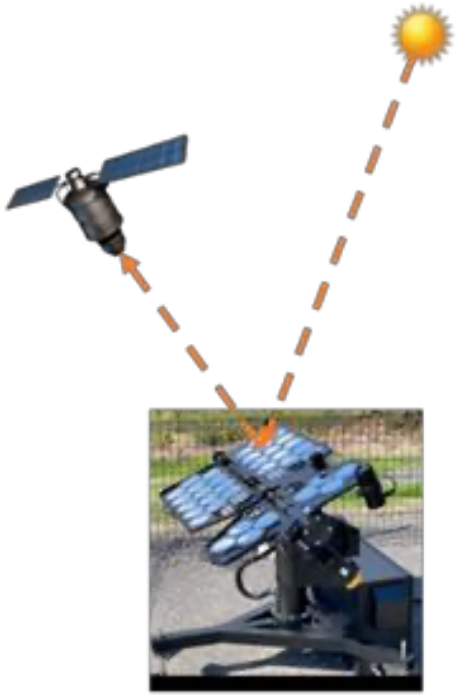
After Disaster (w/o Atmospheric Correction)



After Disaster (w/ Atmospheric Correction)

Precise Mirror-Based Calibration

- Utilize the SPecular Array Radiometric Calibration (SPARC) method with convex mirror arrays to derive calibration coefficients.
- Known Lambertian Equivalent Reflectance (LER) and minimal BRDF.
  - Can improve relative radiometric accuracy, cross-sensor harmonization, detector linearity etc.
  - Can monitor sensor degradation with time
- This site is well-suited as an add-on calibration system helping in reducing the RadCalNet visit frequency



$$L_m\lambda, \theta_i = \frac{1}{4} E_0 \lambda \rho_m \lambda, \theta_i \tau_{\downarrow} \lambda \tau_{\uparrow} \lambda \frac{R_c^2}{GSD_c GSD_a}$$

where:

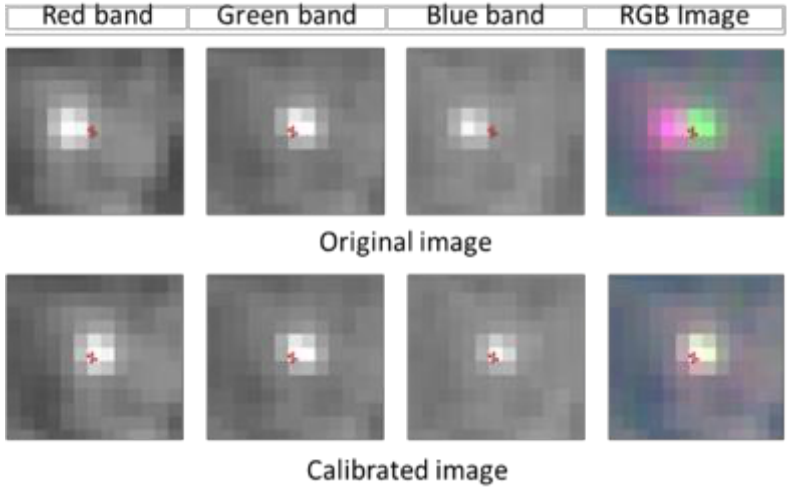
ρ_m: specular reflectance of the mirrors (unitless)
GSD: ground sample distance, cross/along (m)
E_0: top of atmosphere solar irradiance (W/m^2/nm)
$\tau_{\downarrow}$: downwelling atmospheric transmittance, sun to mirror (unitless)
$\tau_{\uparrow}$: upwelling atmospheric transmittance, mirror to sensor (unitless)
R_c: mirror radius of curvature (m)

SPARC equation

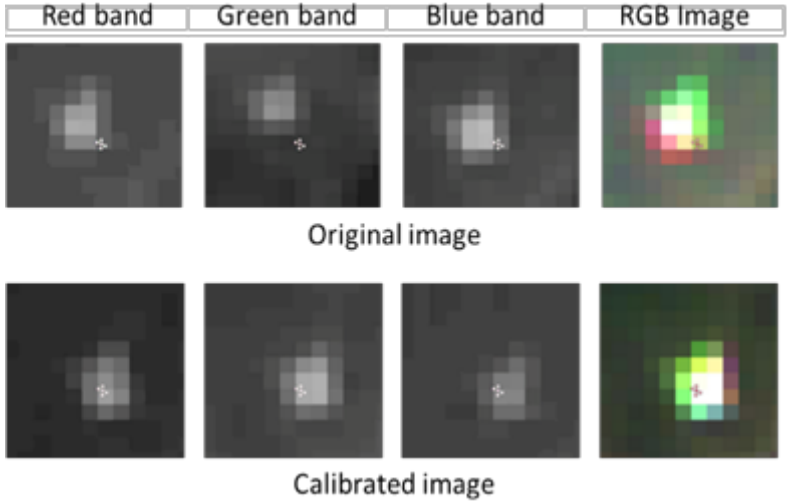
Improvement in Sub-pixel geometric accuracy

- Ground mirror reflector station allows precise estimation of positional accuracy of the mirror pixel at sub-pixel level.
- The mirror-array shows that the single band has different locational accuracy with 2.5m -12.5m.
- The difference in pixel location in the RGB bands tells us band registration accuracy and it makes an image blurring effect in color composite.

Satellite 1A



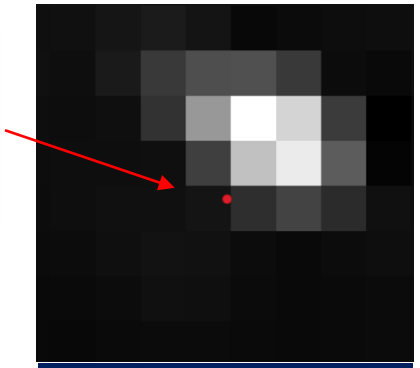
Satellite 1B



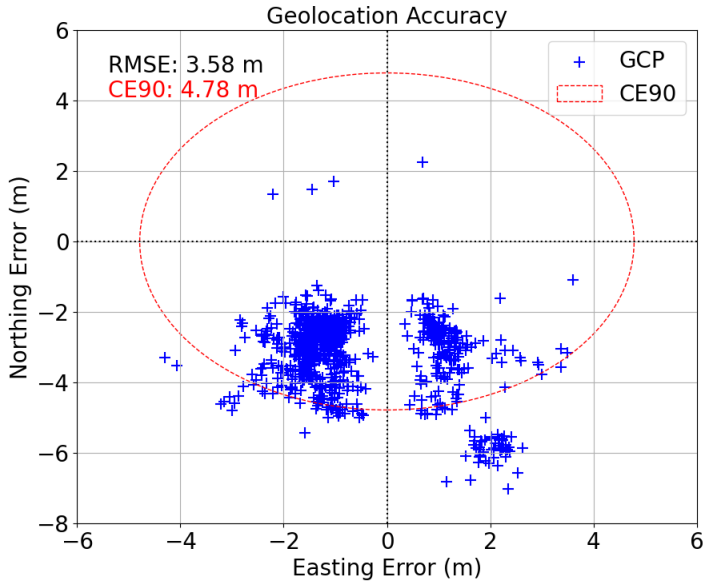
Enhanced geolocation accuracy

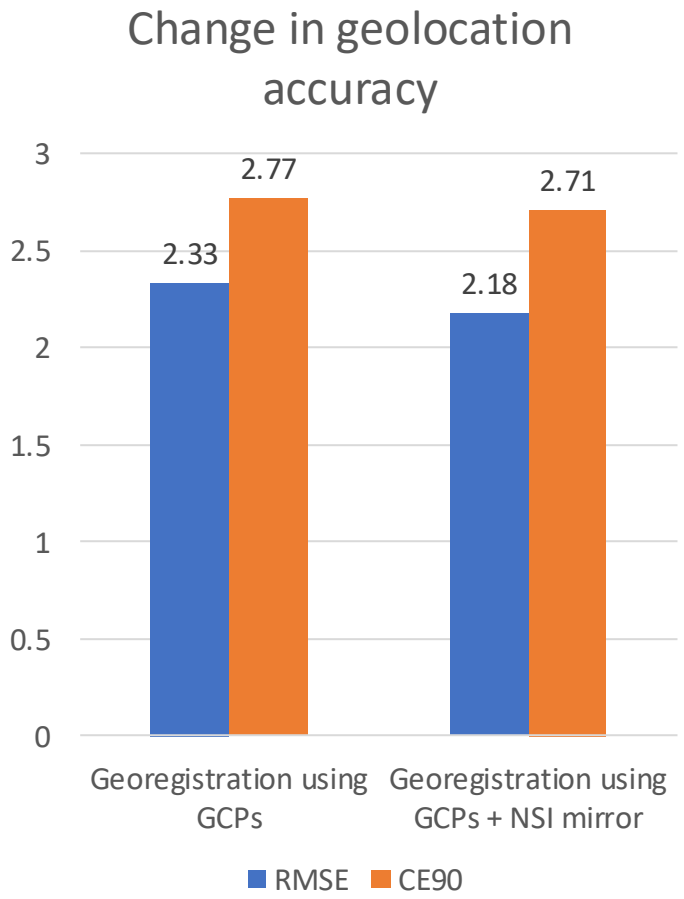
Sample Satellite(red band)

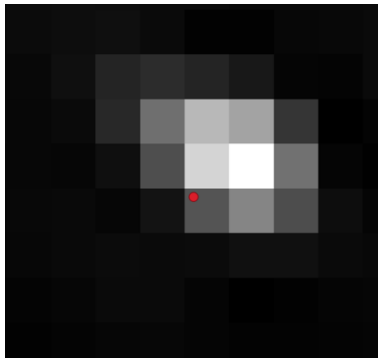
Location of mirror



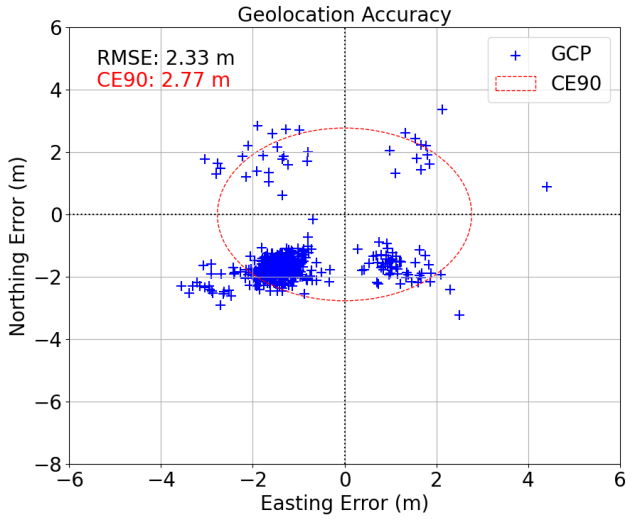
Before

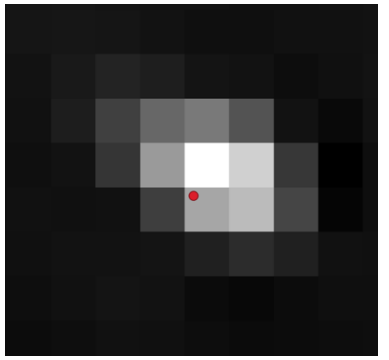




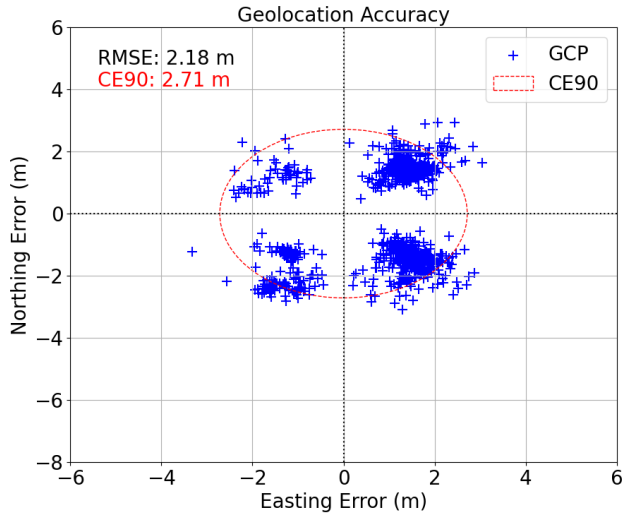


Using GCPs





Using GCPs + NSI mirror

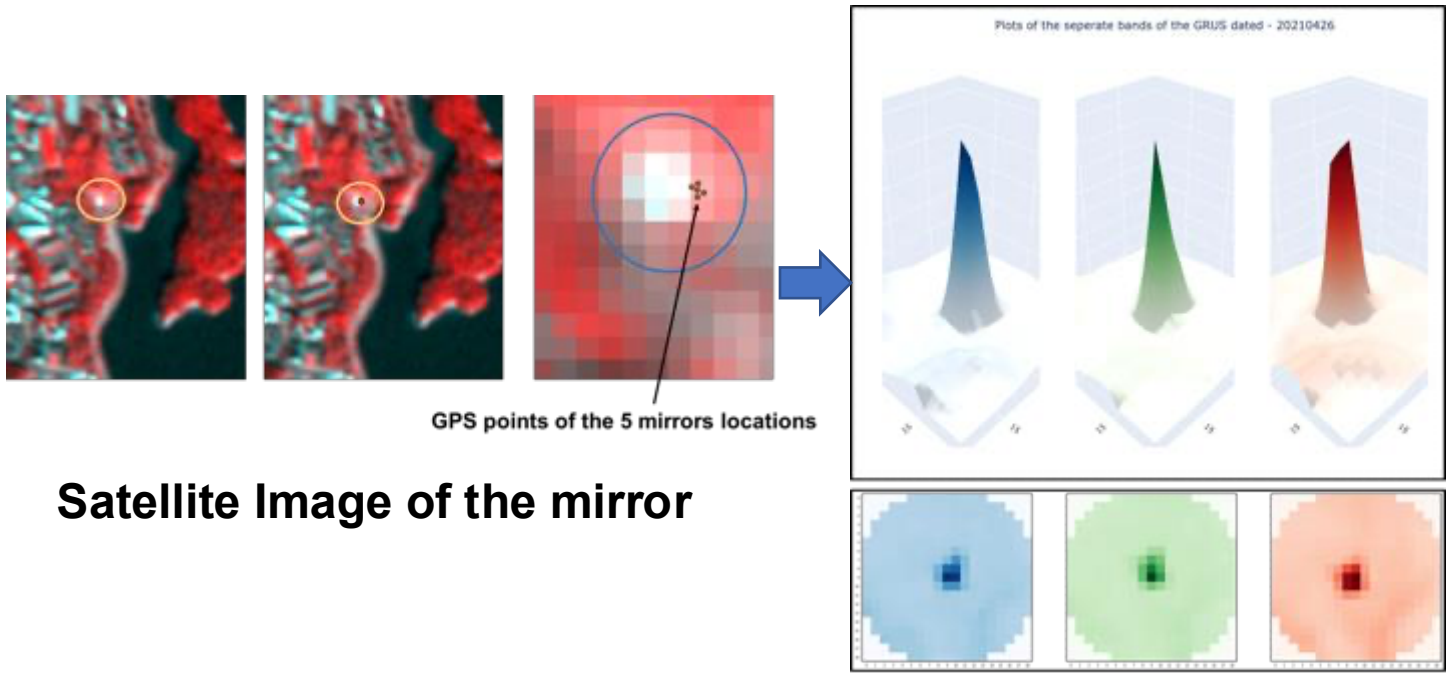


NSI New Space Intelligence

Measuring the spread of the reflected energy from the mirrors for generating **IPSF**

- The distribution and spread of light energy reflected from the mirrors show that NSI has a potential to construct a point spread function from in-flight image. Here oversampling will be important.

- **Point Spread Function (PSF):** is the response of the **optical system** to the point light source. It is a direct measuring by the optical system and determination of the function for light spectrum spread around the point source.
- **In-flight Point Spread Function (IPSF):** is the PSF which is constructed from **satellite image pixel**. IPSF can be constructed on the base of light spectrum spread around the image pixel.



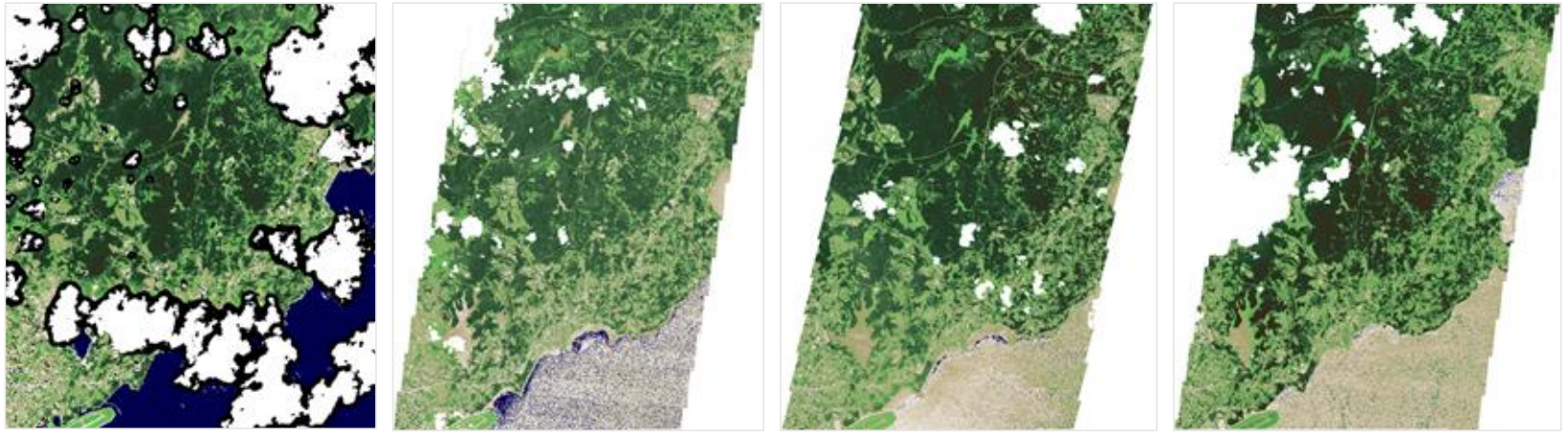
Satellite Image of the mirror

Use of IPSF for image quality enhancement

How IPSF Improves Image Quality

- The mirror system creates precise, bright point targets.
- Apply precise deconvolution to reverse the blur.

Effect of harmonization



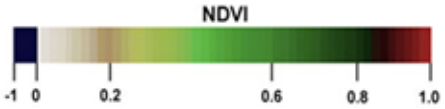
Sentinel-2
2025-08-23

NUSAT-26
2025-08-21

NUSAT-41
2025-08-24

NUSAT-45
2025-08-25

NDVI BEFORE HARMONIZATION



NDVI AFTER HARMONIZATION

Why Harmonization Matters

✓ High Interoperability

Smoother integration with existing Sentinel-2, Landsat, Planet workflows

✓ Multi-Sensor Time Series

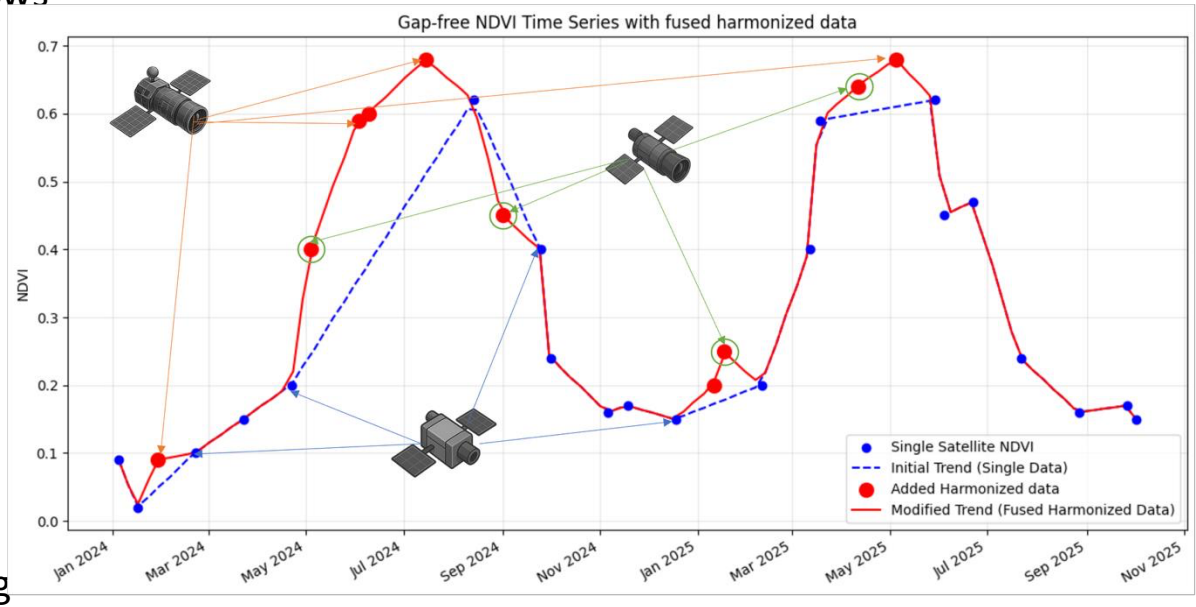
Daily, stable, cross-constellation monitoring

✓ Higher Value, Science-Grade Insights

Reliable and consistent analytics

✓ AI/ML Ready Data

Standardized reflectance → better training data for accurate modelling

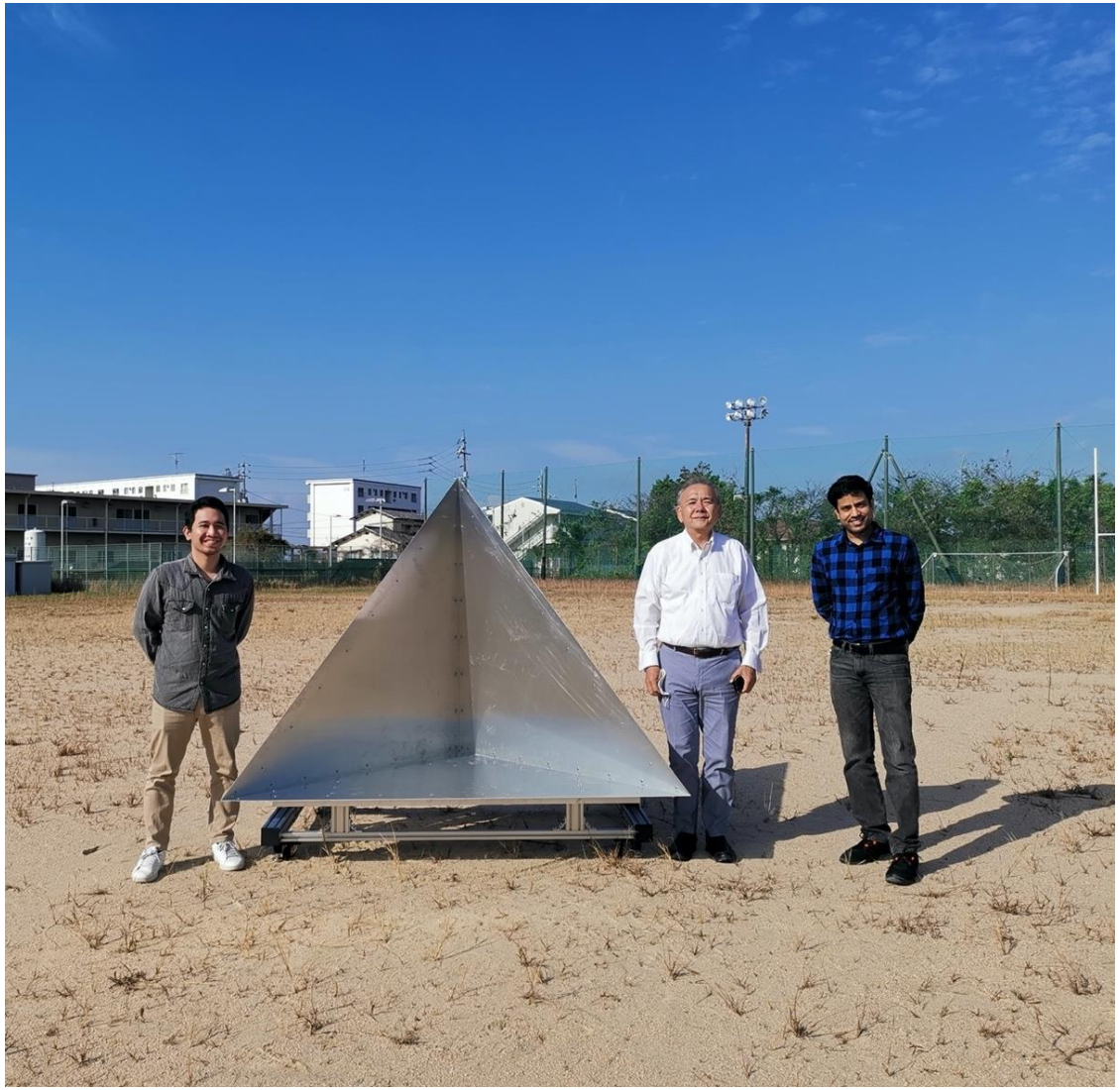


Higher frequency of time-series with harmonized satellite data

SAR Data

CR details

- Shape: Triangular-trihedral CR
- Slant edge length: 141.4 cm
- Height: 100 cm
- Material: Aluminium
- Azimuth angle range: by whole CR rotation using attached wheels, 0~360°
- Tilt angle range: 0~40°

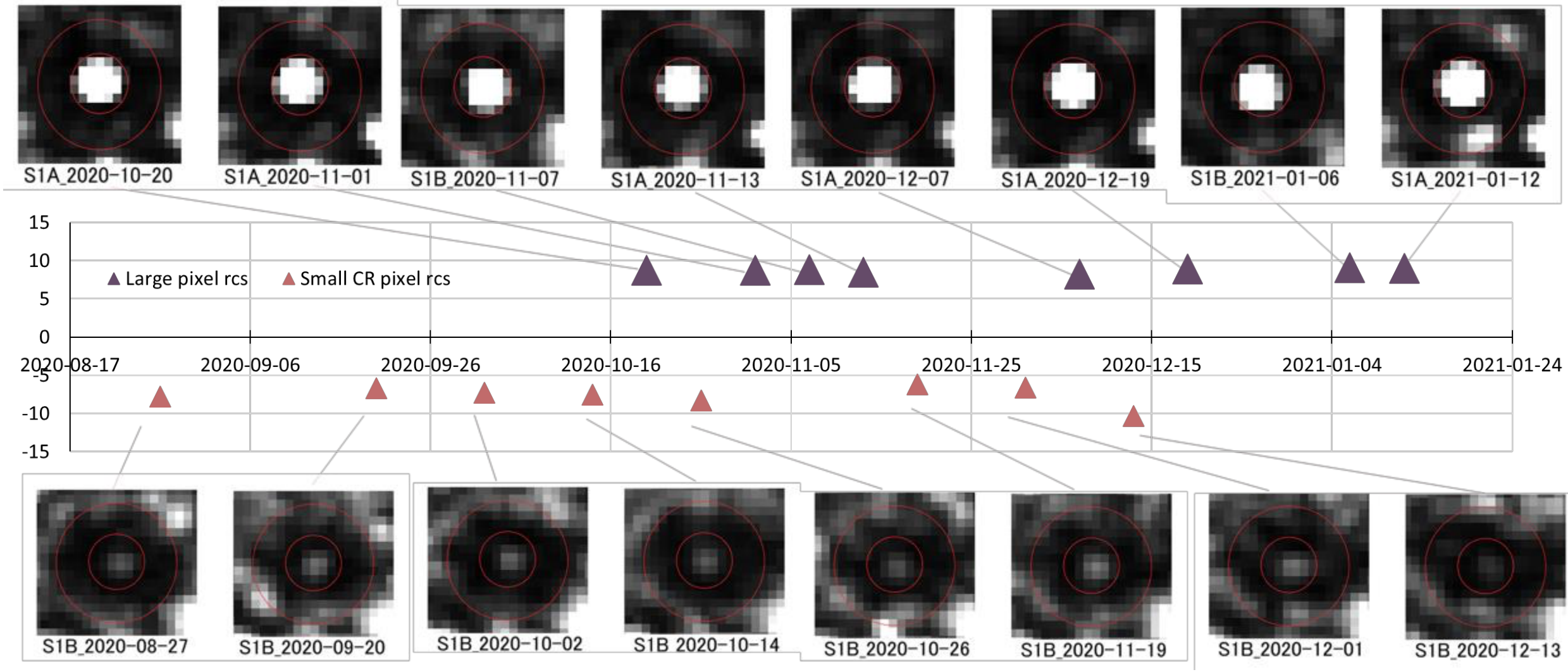


Experiments with Corner reflector

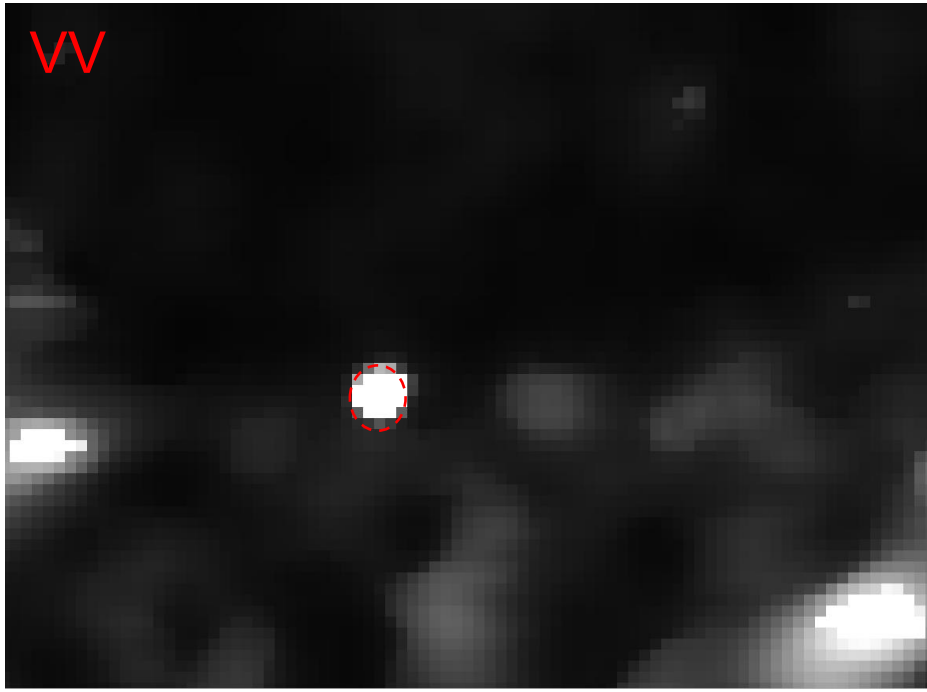





Experiments with Corner reflector



CR in different polarization bands



Thank you for your kind attention

Please feel free to reach out!