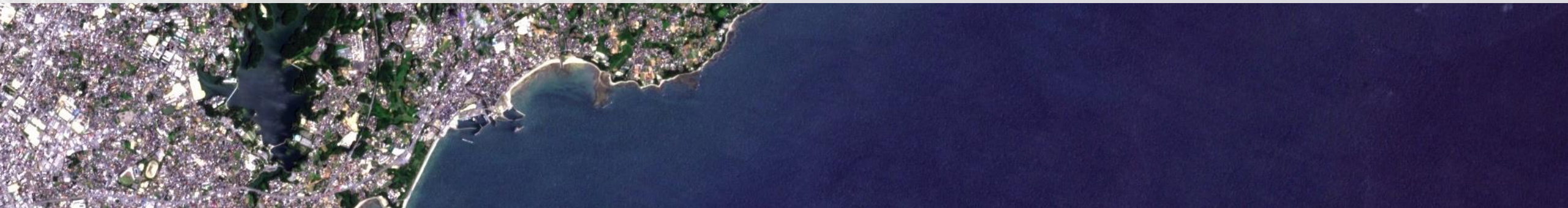
Calibration and Harmonization for Multi-Satellite Utilization

Masahiko Nagai

Center for Research and Application of Satellite Remote Sensing (YUCARS)
Yamaguchi University



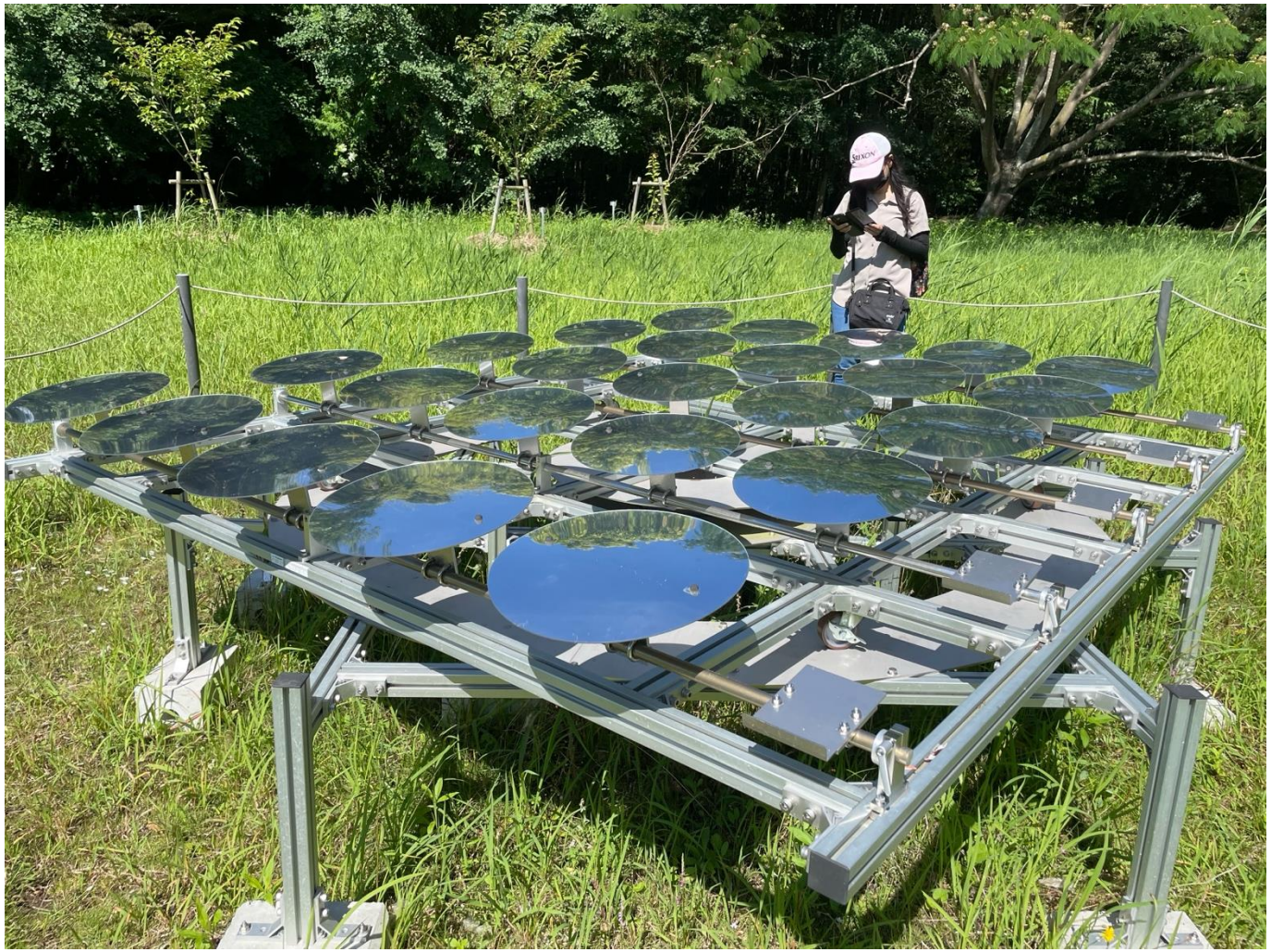
Main problems for EO data utilization

- Variation in spatial, spectral, radiometric properties in inter-constellation or intra-constellation satellites.
- Lower frequency (revisit time is high)
- Requirement of sudden event capture before and after the disaster quickly by the same sensor
- Getting cloud-free images (revisit time is high and if miss the capture due to cloudy condition then next chance will come after long time)
- Creating the common training data from existing public data and use of transfer learning

To solve these problems, we need to start thinking about
Calibration & Data Harmonization

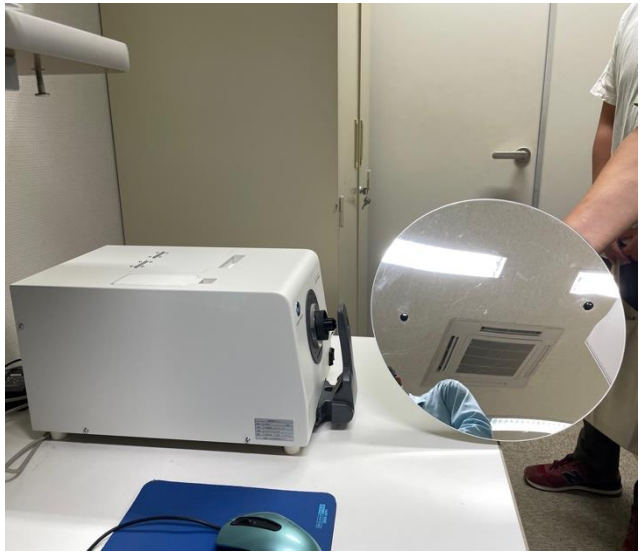
Large fixed Mirror Array (Tokiwa site)

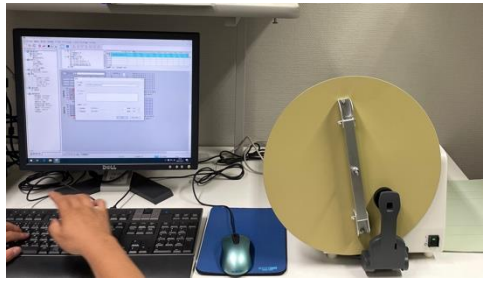
- Established in March 2021.
- With an aim to use this site as add-on to the vicarious calibration site. Requires less man power, due to the known surface reflectance with less BRDF effect.
- The total Lambertian Equivalent Reflectance (LER) can be controlled by keeping some mirror in different offset.

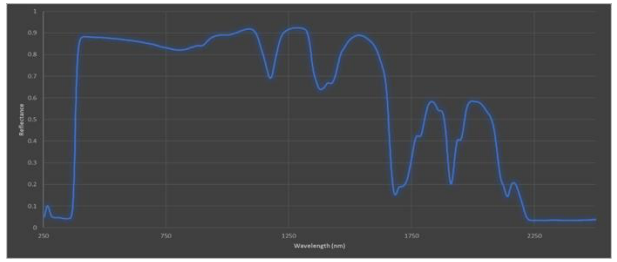


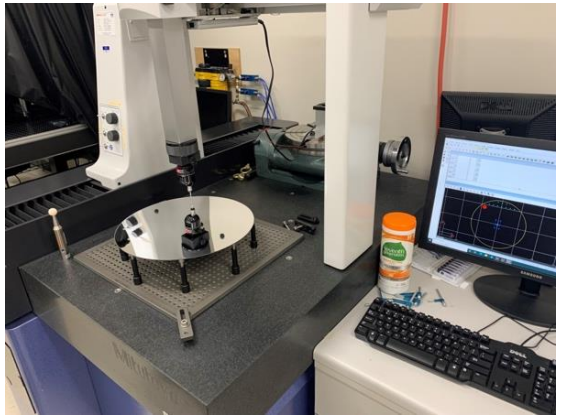
Mirror reflectance measurement in the lab

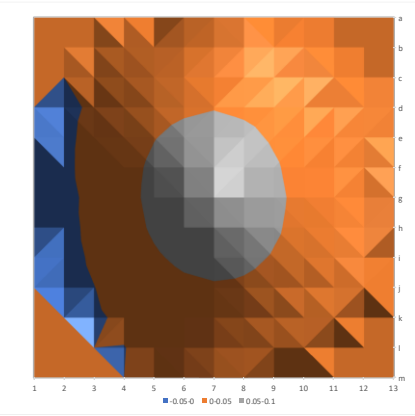
- Mirror reflectivity measured in the lab in Japan and at Labsphere USA.
- The measured range was in between the visual range i.e. 350 to 750 nm in Japan and in USA the range was till 2000 nm.
- We have reconfirmed the condition of the mirrors' reflectivity after use of three years and found that the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







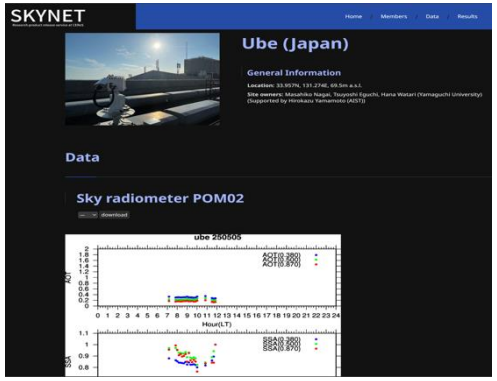




Atmospheric Measurements

Skyradiometer POM-02

Sky camera



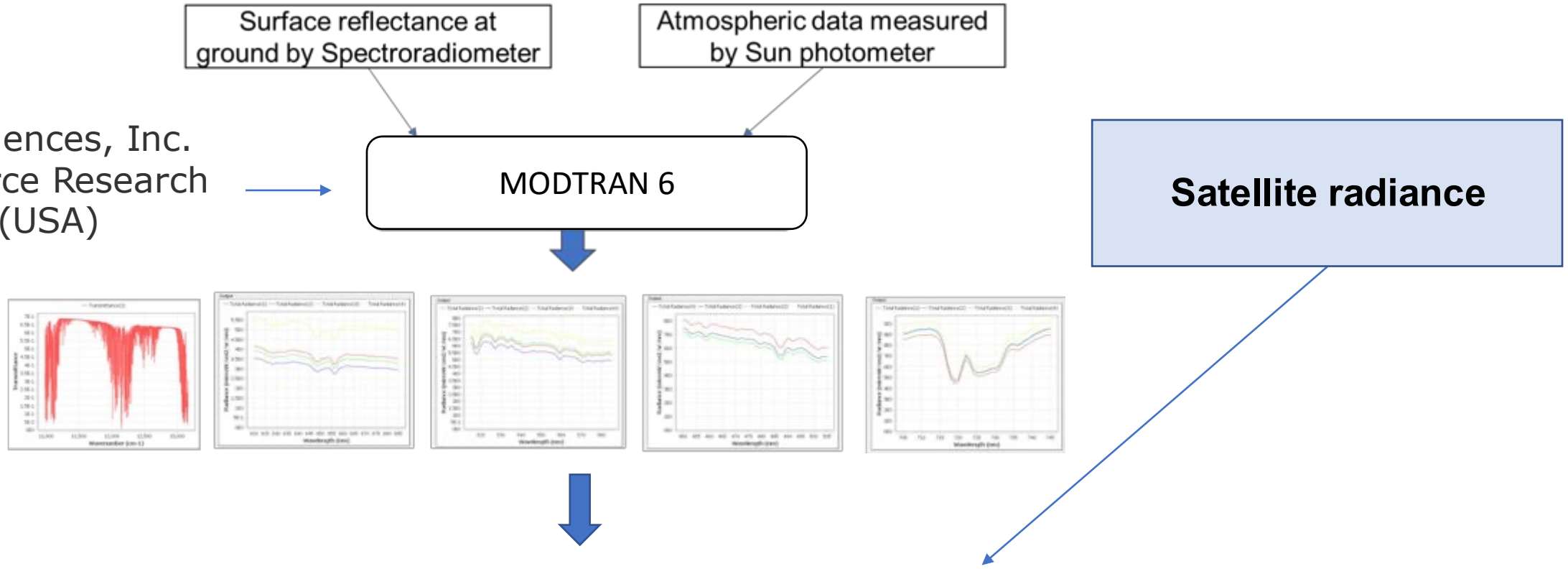
Data access

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.

Estimation of TOA radiance using MODTRAN-6

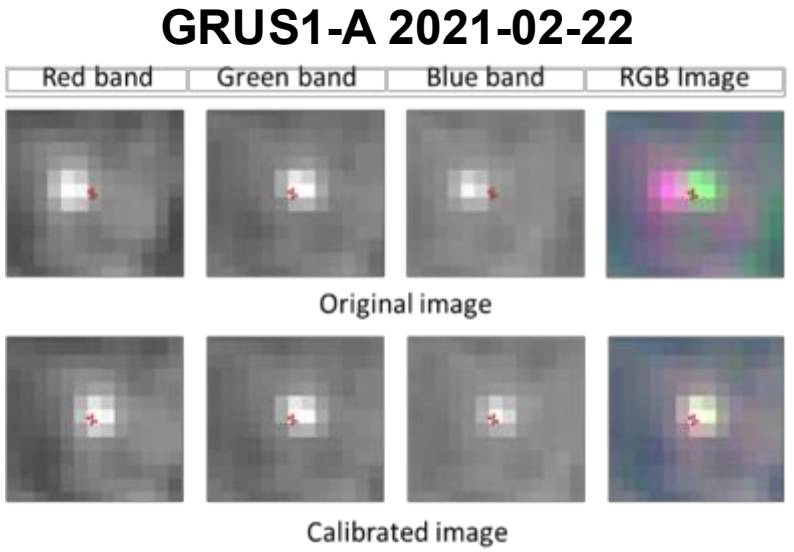
Spectral Sciences, Inc. and Air Force Research Laboratory (USA)

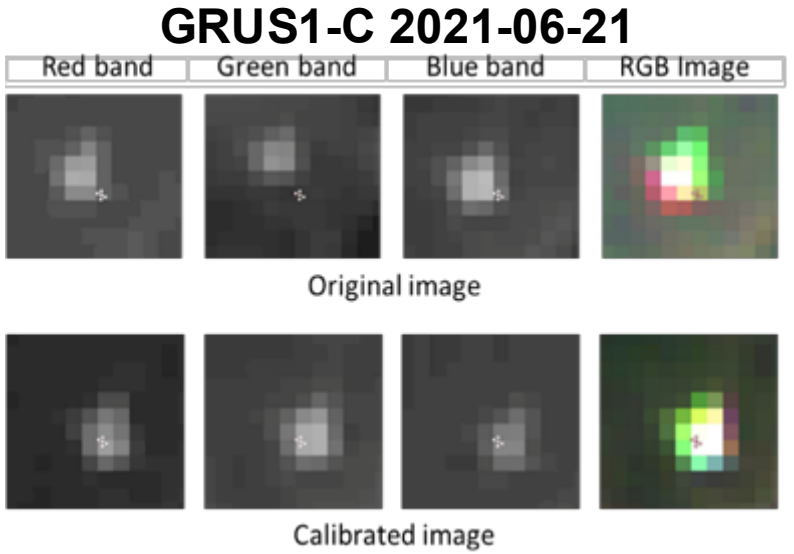


	Band 1	Band 2	Band 3	Band 4	Band 5
Satellite pixel values	6.354 %	5.991 %	3.395 %	7.686 %	11.659 %
Modtran Simulated values	6.349 %	5.912 %	3.746 %	7.811 %	11.793 %
Difference (Satellite - Modtran)	0.005	0.079	-0.351	-0.125	-0.134
Difference (%) (Difference/ Modtran)	0.077%	1.338%	-9.372%	-1.604%	-1.133%

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.

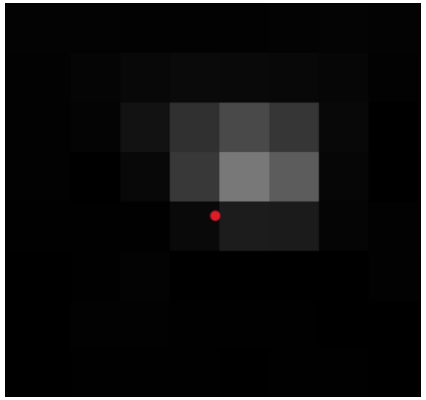




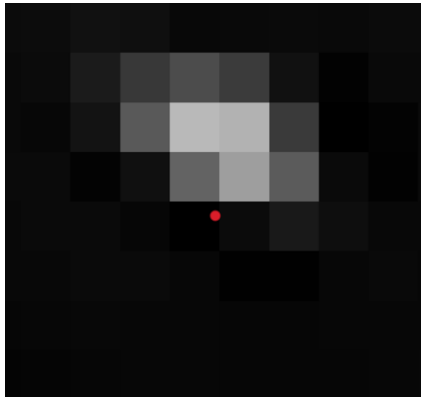
Improved band-to-band accuracy

BEFORE

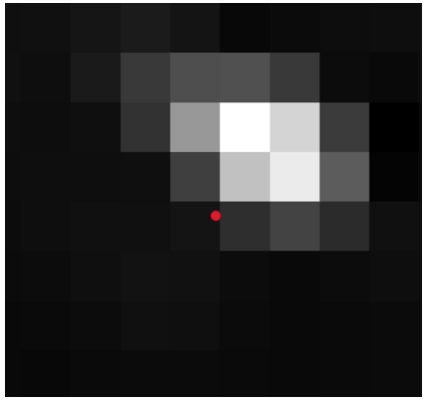
< 0.8 pixel



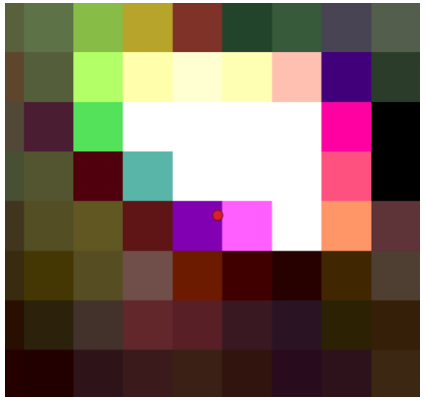
Blue band



Green band



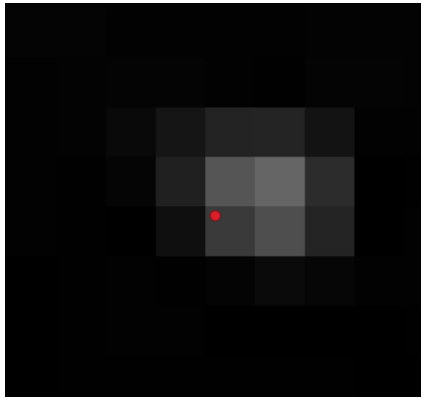
Red band

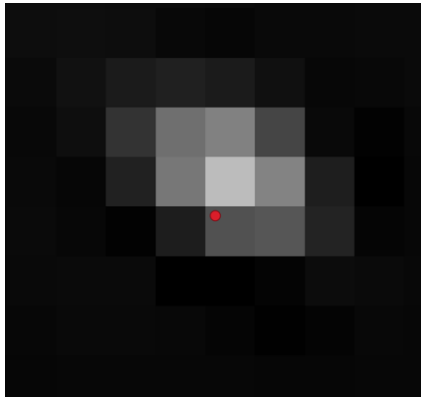


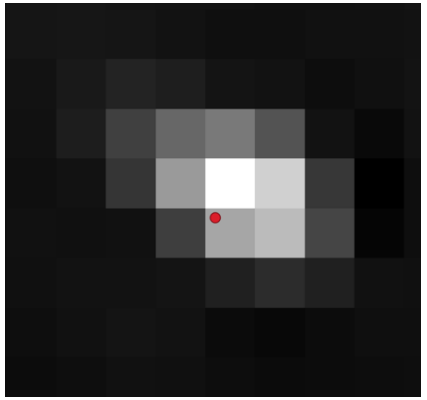
RGB image

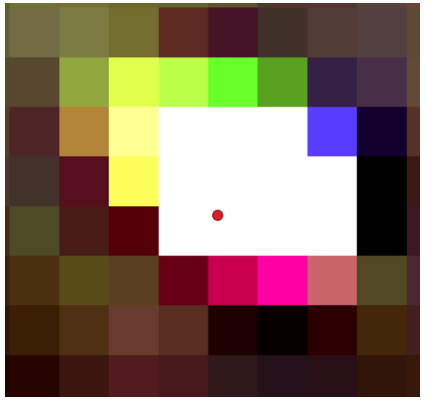
AFTER

< 0.5 pixel



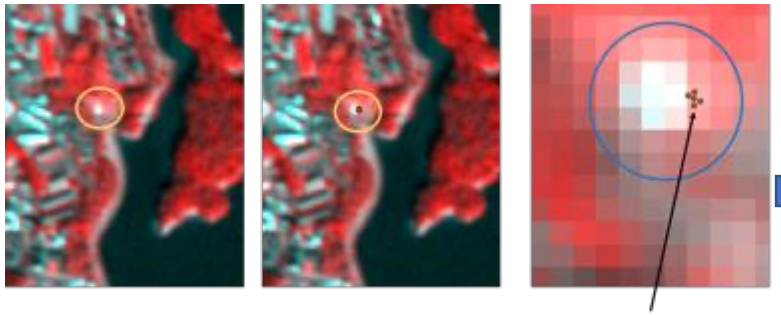




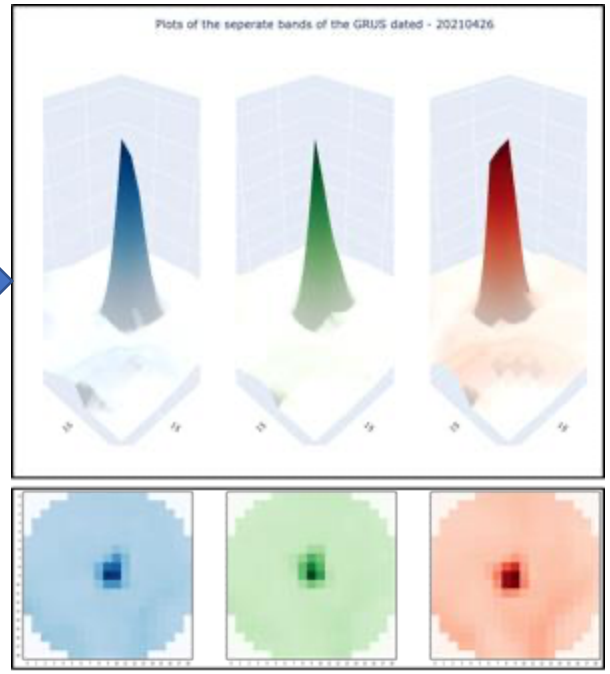


Measuring the spread of the reflected energy from the mirrors for generating IPSF

- **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.



GRUS image of NSI mirrors



GRUS1-A 2021-04-26

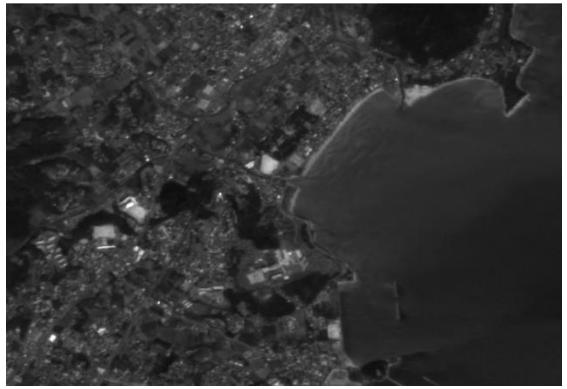
Use of IPSF for image quality enhancement

The construction of the calibration site based on mirror reflector contributes following significant achievement for satellite remote sensing technology:

1. A spread of light spectrum of satellite image pixel has been analyzed for IPSF
2. IPSF's parameters as FWHM and sigma for GRUS1 image have been determined
3. Satellite image processing in spatial and frequency domain has been adopted for GRUS1 images
4. The IPSF has been applied to image reconstruction to remove blurring effects from the satellite image.

Original image

Improved image



Original image

Improved image

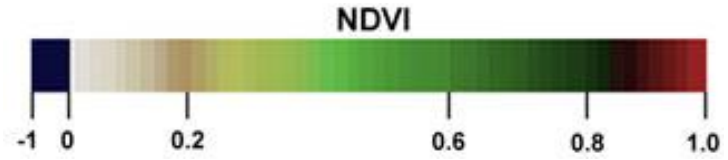
Before

After deblurring

Effect of calibration on NDVI

Before calibration

After calibration



	PlanetScope PS2	PlanetScope PSB.SD	GRUS1
Date:	2022-08-05	2022-08-05	2022-08-05
Local Time:	10:34 am	10:11 am	10:47 am

New Space Intelligence

Thank you for your kind attention

SiP 戦略的イノベーション創造プログラム
Cross-ministerial Strategic Innovation Promotion Program

YAMAGUCHI UNIVERSITY