Development of Mirror Target Calibration for Multiple Optical Satellite Data

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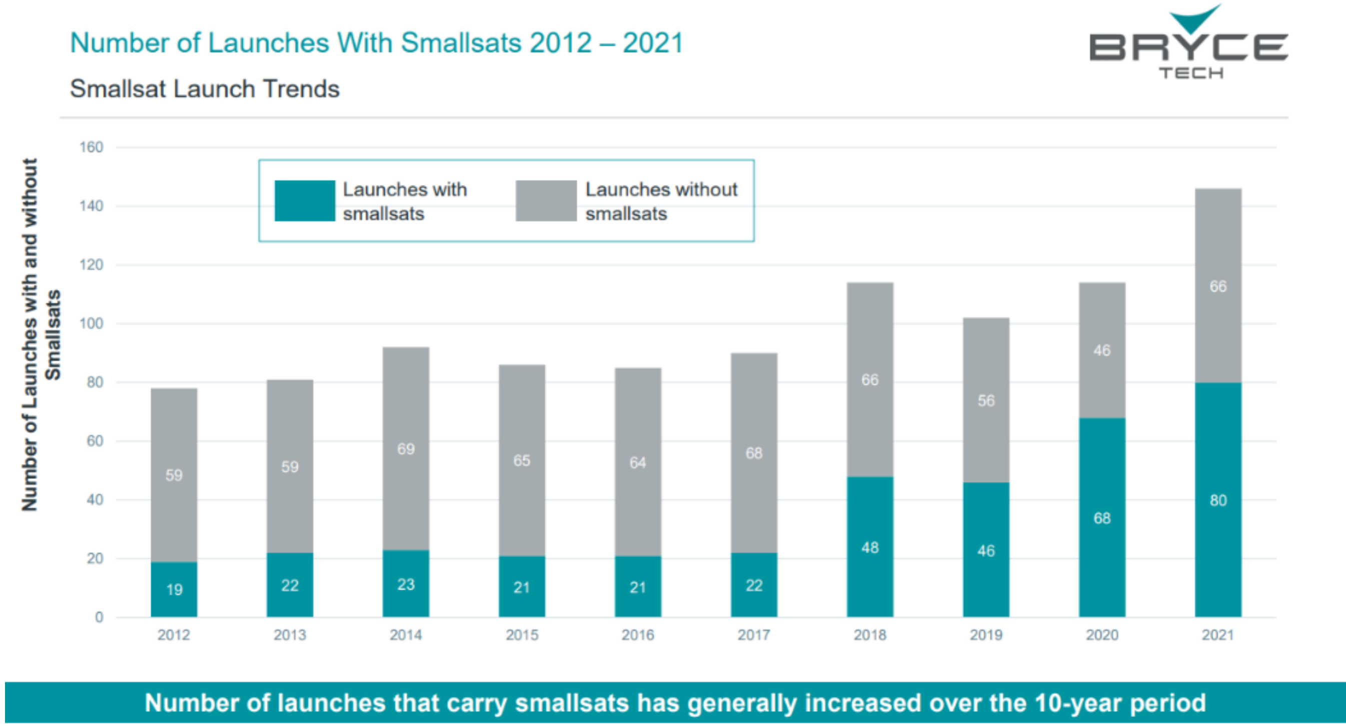
Introduction

- Since the advent of the New Space Ecosystem, microsatellites have been increasing and their commercial use in various application is becoming more common.



[Ref: https://brycetech.com/reports/report-documents/Bryce_Smallsats_2022.pdf](https://brycetech.com/reports/report-documents/Bryce_Smallsats_2022.pdf)

- Moreover, there will be a greater number of microsatellites for earth observation in the future.
- Each satellite sensors have different specifications which resulted into different quality and visualization.
- Therefore, sensor and data calibration is an important step for precise and accurate remote sensing measurement.

Introduction

- Different sensors and environmental conditions affect to the quality of satellite images.

Normalized difference vegetation index (NDVI)


2020-03-20_Planet

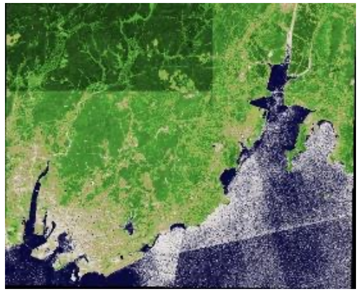

2020-03-23_GRUS


2020-03-24_Planet


2020-03-29_Planet


2020-04-02_Planet


2020-04-04_GRUS


2020-04-07_Planet


2020-04-15_GRUS


2020-04-15_Planet


2020-04-16_GRUS


2020-04-25_Planet


2020-04-29_Planet

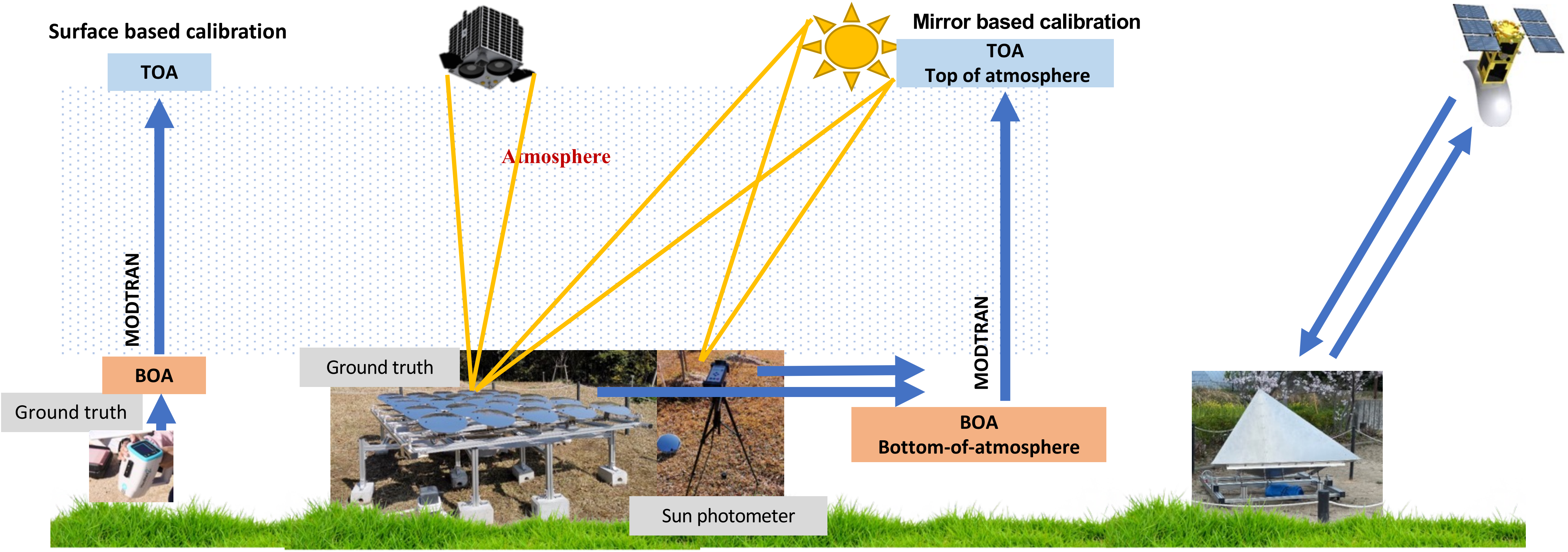
- To utilize multi-sensor satellite images for data application, the radiometric calibration is very crucial for evaluating quality and calibrating satellite data to be more precise and well harmonize for real world applications.

Introduction:

Yamaguchi Univ. builds calibration sites for current and upcoming new microsatellites.

- Selected/constructed optical satellite data calibration sites based on
  - Surface reflectance measurements
  - Ground point source-mirror reflectors
- Constructed SAR satellite data calibration site
  - Corner reflector

Data calibration
Data utilization
(Disaster,, Infrastructure and environment monitoring)

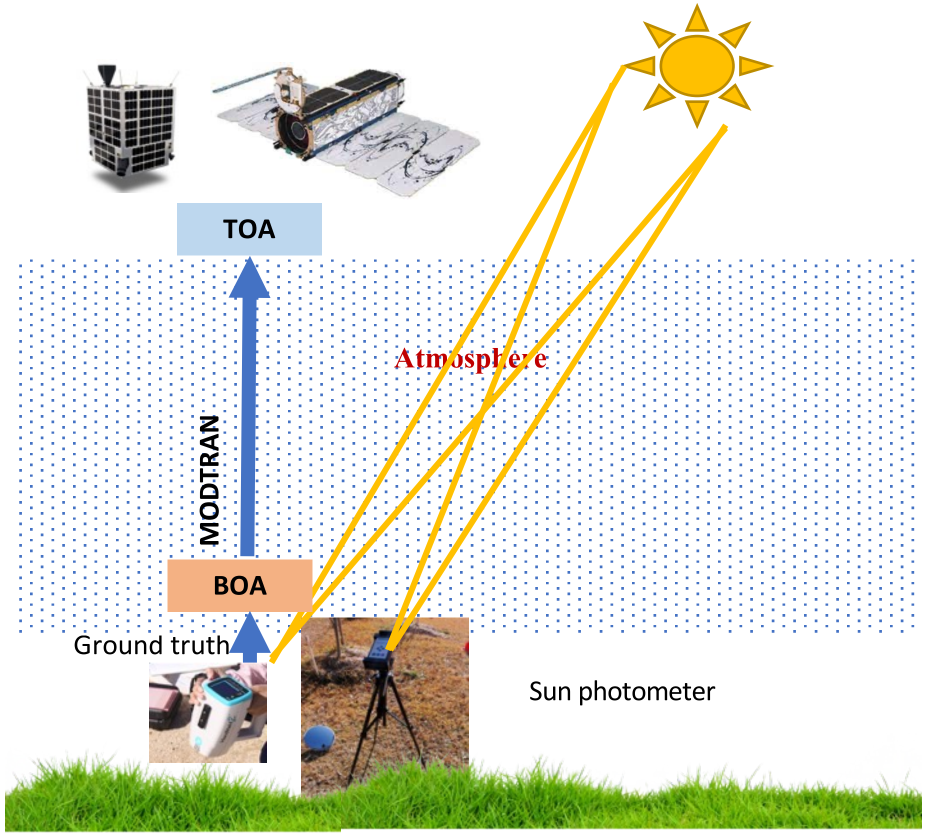


Introduction and objective

- In previous studies, radiometric calibration has been successfully performed using artificial objects such as permanent back and white area.
- In case of conventional calibration site such as permanent back and white area, it is difficult in Japan because un-utilized area is limited.

Objective

- Yamaguchi Univ. has established a calibration site based on convex mirror array at Ube city, Yamaguchi Prefecture, Japan.
- The main goal of the project is to make better quality, better accuracy, better harmonization of multi-sensor satellite, especially constellation satellites.



Data used

Satellite constellation

5 GRUS satellites

~130 PlanetScope satellites

5August 2021

GRUS1A

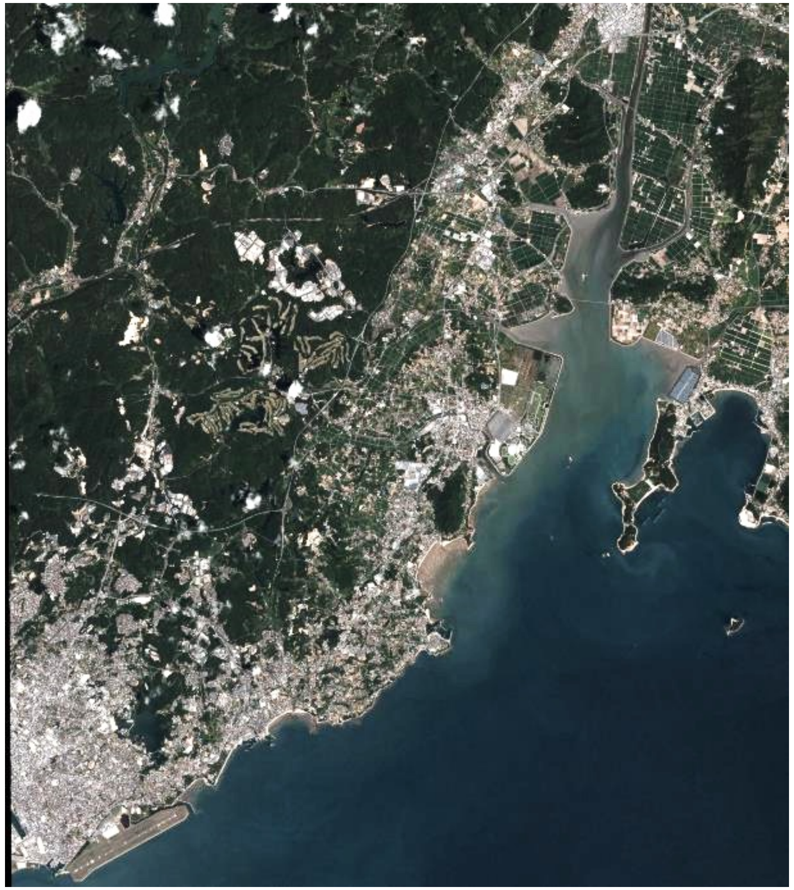
PlanetScope PS2

PlanetScope PSB.SD

Spectral bands	Panchromatic	450-900 nm
	Blue	450-505 nm
	Green	515-585 nm
	Red	620-685 nm
	Red Edge	705-745 nm
	Near Infrared	770-900 nm
	Swath	57+ Km
Ground resolution	Panchromatic	2.5 m
	Multispectral	5.0 m

Instrument	PS2	PSB.SD
Spectral Bands	Blue: 455 - 515 nm Green: 500 - 590 nm Red: 590 - 670 nm NIR: 780 - 860 nm	Blue: 465 - 515 nm Green: 513 - 549 nm Red: 650 - 680 nm Red-Edge: 697 - 713 nm NIR: 845 - 885 nm (8-band will be released in the future)
Resolution	3.125 m	

True color composite

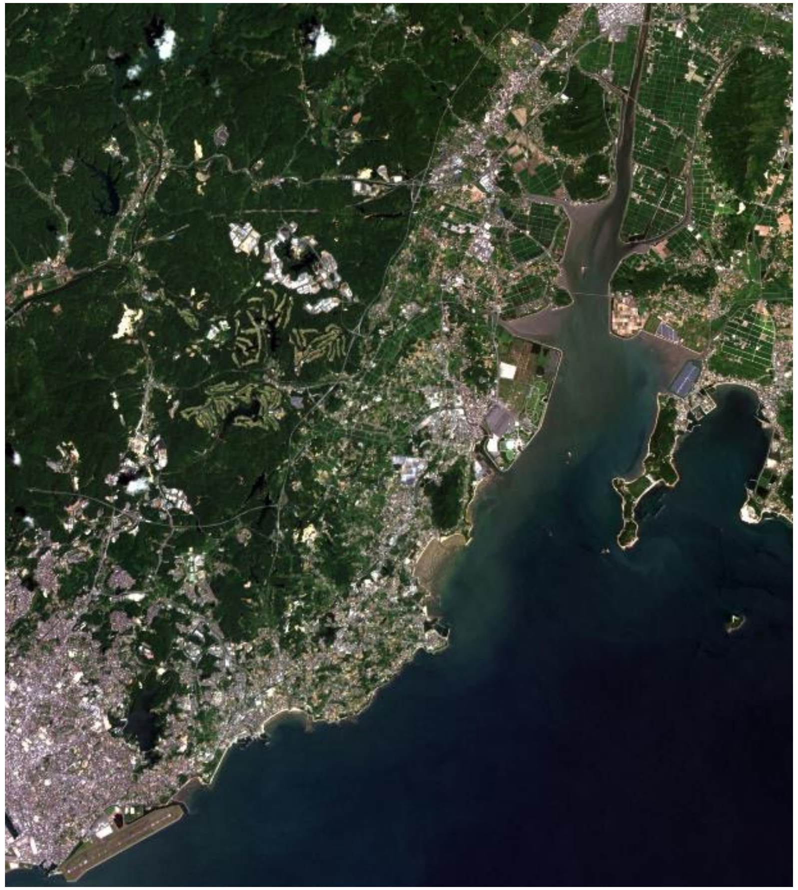


PlanetScope PS2

Date: 2022-08-05
Local Time: 10:34 am.

PlanetScope PSB.SD

Date: 2022-08-05
Local Time: 10:11 am.



GRUS1

Date: 2022-08-05
Local Time: 10:47 am.

Ground data collection

- Surface reflectance by Spectroradiometer
  - HandHeld 2
- Atmospheric measurements by Sunphotometer
  - MICROTOPS II 540
- Location of the measurements by GPS
  - Garmin etrex20xJ
  - Garmin GPS73 and Ichimill GPS

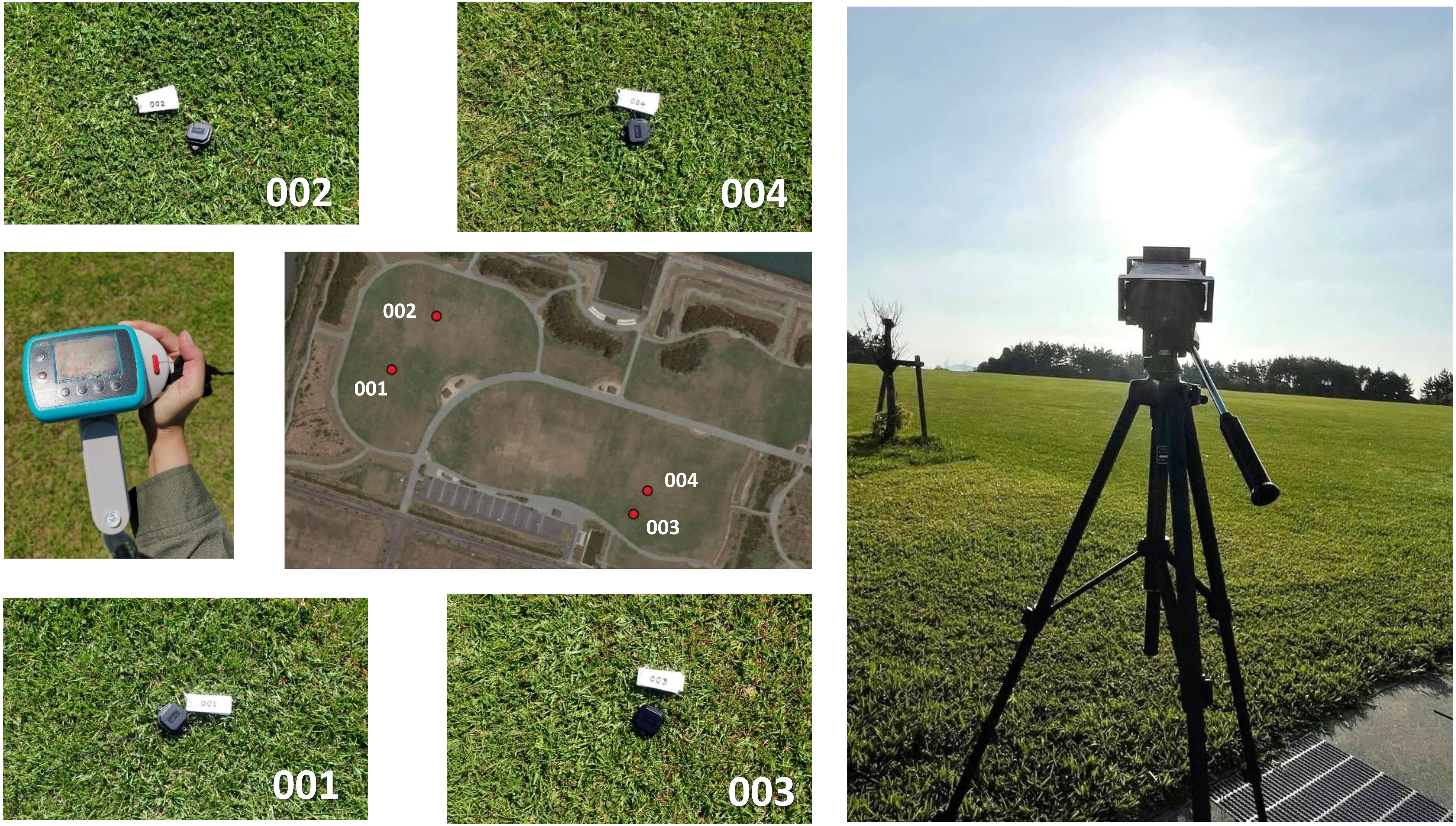
HandHeld 2

Ichimill GPS
(3 cm resolution)

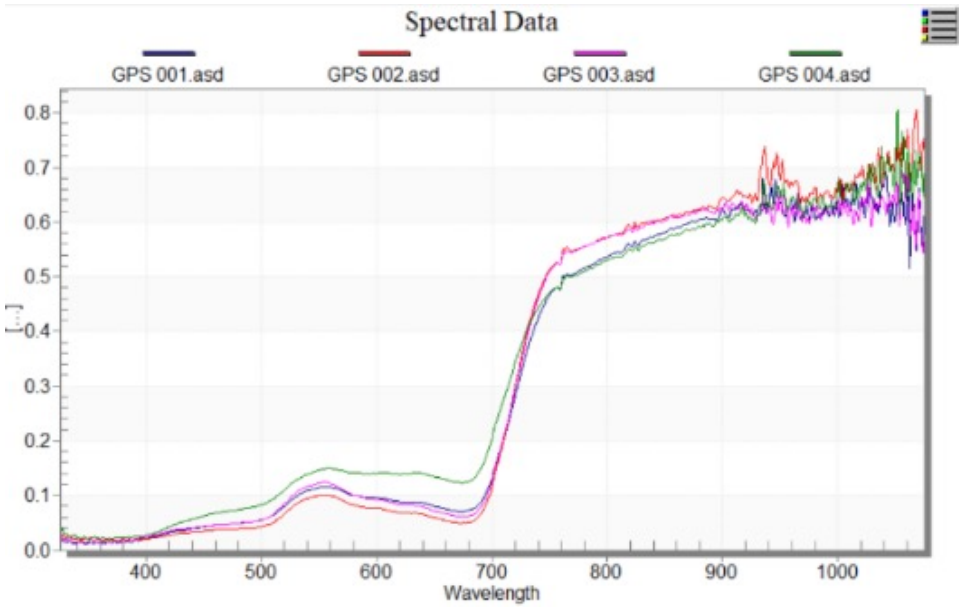
Garmin etrex20xJ

Garmin GPS73

Microtops II 540


002
004
002
001
004
003
001
003

Spectroradiometer



GRUS1A

File Name	RED	RED_Edge	GREEN	BLUE	NIR
001.asd.	0.079784	0.313083	0.103196	0.049014	0.565574
002.asd.	0.058683	0.334836	0.087877	0.038922	0.595021
003.asd.	0.071731	0.33167	0.108437	0.049056	0.591496
004.asd.	0.132771	0.3617	0.136567	0.073323	0.556273

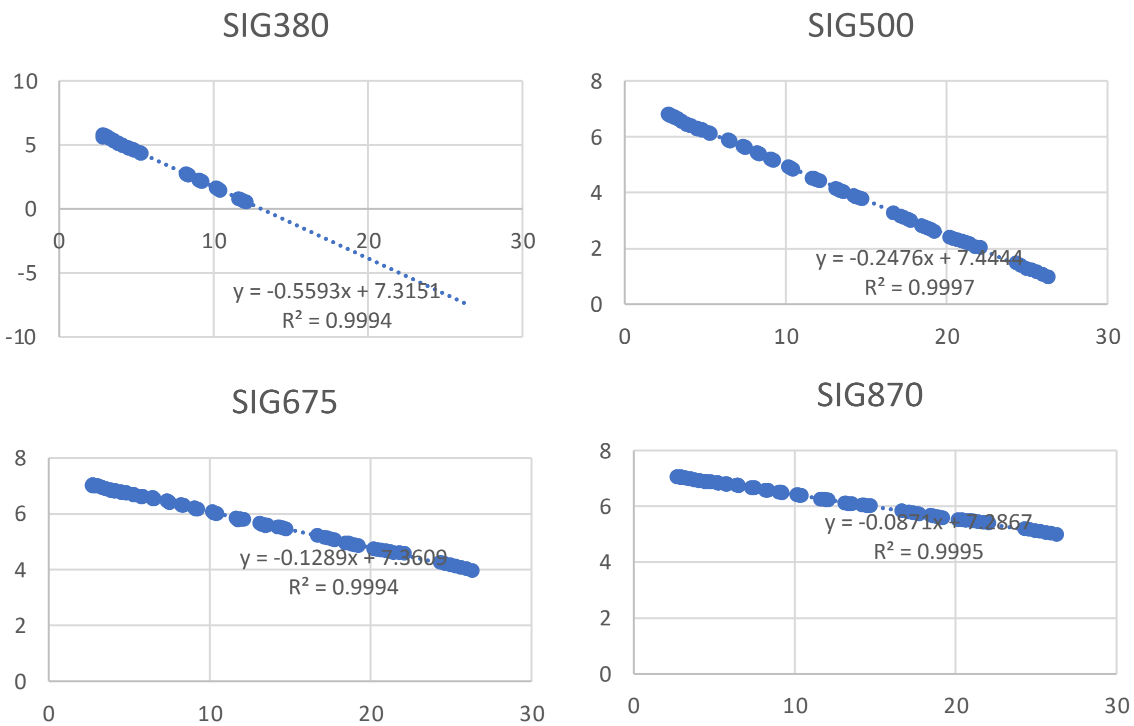
PlanetScope PS2

File Name	RED	GREEN	BLUE	NIR
001.asd.	0.086335	0.095922	0.051939	0.554396
002.asd.	0.066028	0.08073	0.041078	0.586623
003.asd.	0.08049	0.100042	0.052045	0.583822
004.asd.	0.136882	0.129038	0.077406	0.545775

PlanetScope PSB.SD

File Name	RED	GREEN	BLUE	NIR
001.asd.	0.074076	0.109549	0.053835	0.59422
002.asd.	0.052802	0.093105	0.042445	0.616047
003.asd.	0.064865	0.113923	0.053947	0.612558
004.asd.	0.127271	0.145639	0.080133	0.581955

Calibration of Sun photometer Microtops II



Band name	Langley plot line	The extraterrestrial constant Vo	
380nm	y = -0.5593x + 7.3151	7.3151	R^2 = 0.9994
500nm	y = -0.2476x + 7.4444	7.4444	R^2 = 0.9997
675nm	y = -0.1289x + 7.3609	7.3609	R^2 = 0.9994
870nm	y = -0.0871x + 7.2867	7.2867	R^2 = 0.9995
1020nm	y = -0.0775x + 7.3733	7.3733	R^2 = 0.9972

Angstrom exponent

An Aerosol Optical Properties can be determined by Angstrom coefficient.

$$\alpha = -\frac{\ln(\tau_{0.5}) - \ln(\tau_{0.87})}{\ln(0.5) - \ln(0.87)}$$

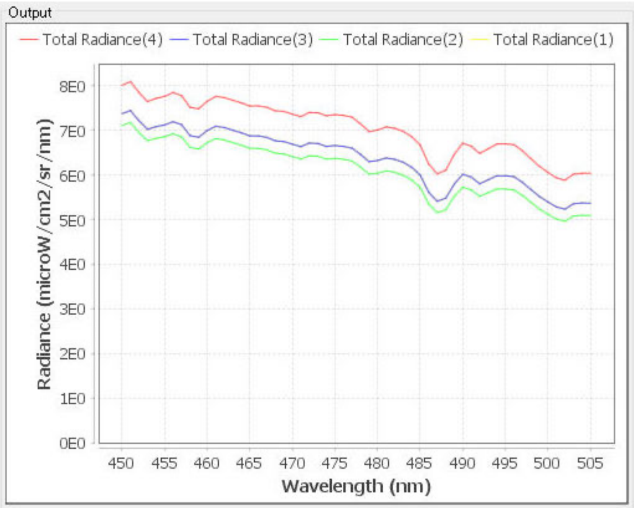
Kirara 2021/08/05

Sig500 = 1478.84

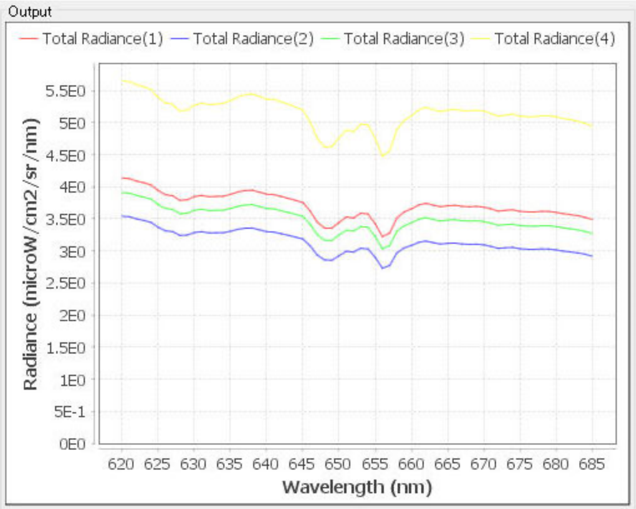
Sig870 = 1397.49 Angstrom exponent = 0.102151556

MODTRAN output sample (TOA Radiance)

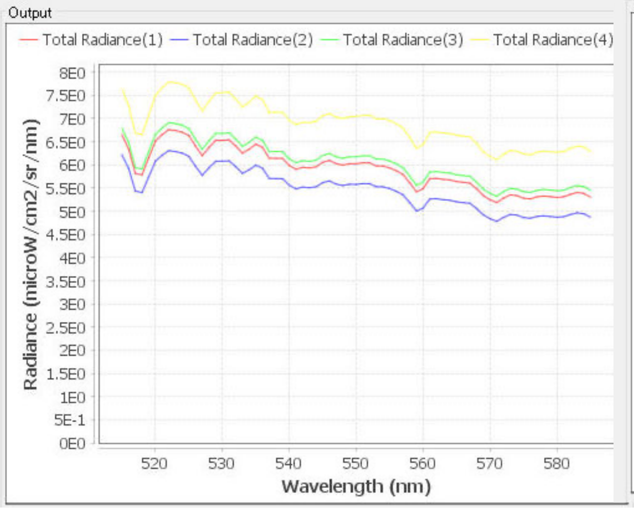
Blue



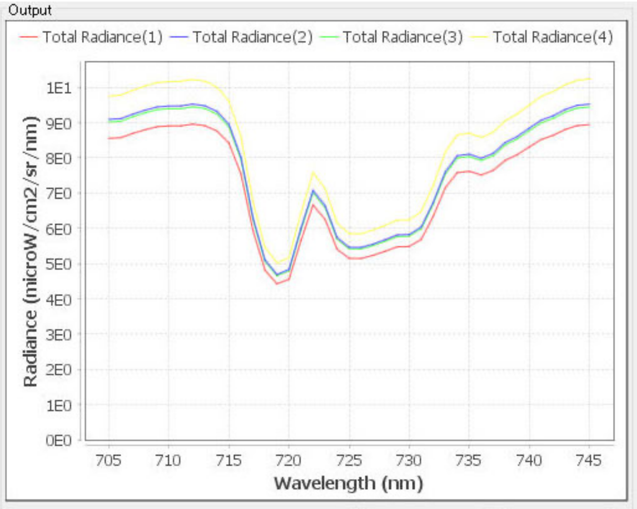
Green



Red

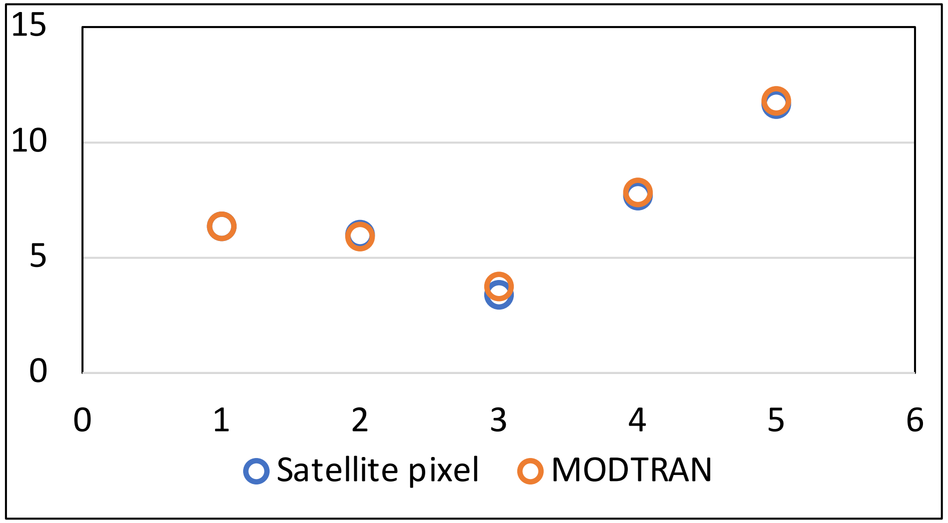


NIR



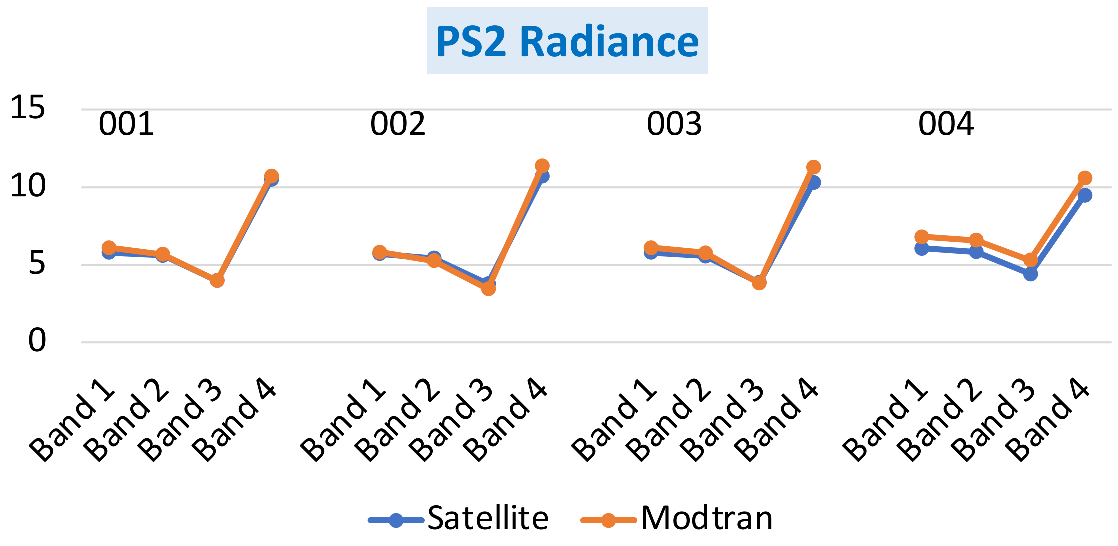
GRUS-1A

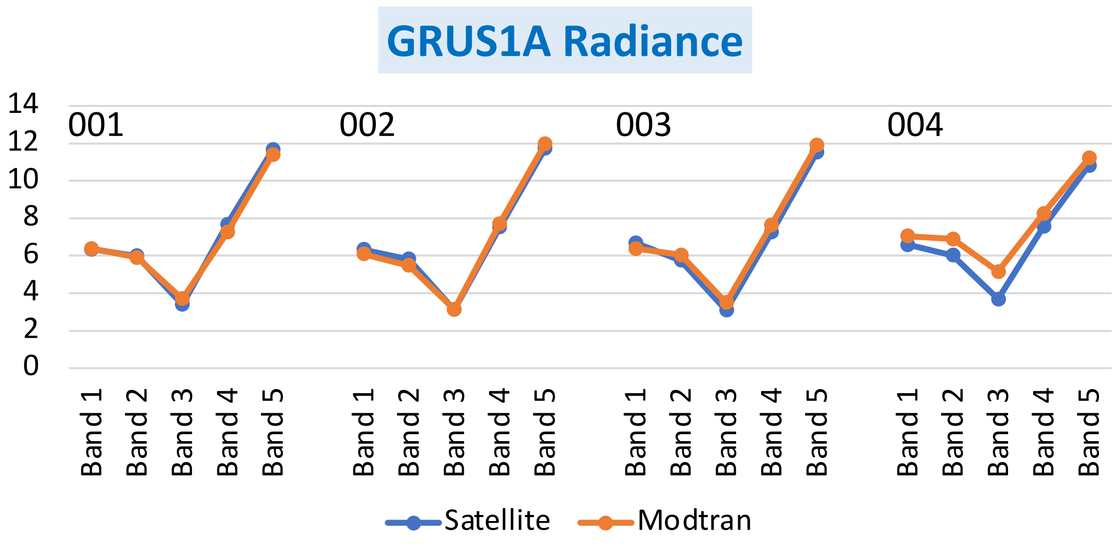
Comparison of TOA radiance and reflectance estimated from MODTRAN and satellite images

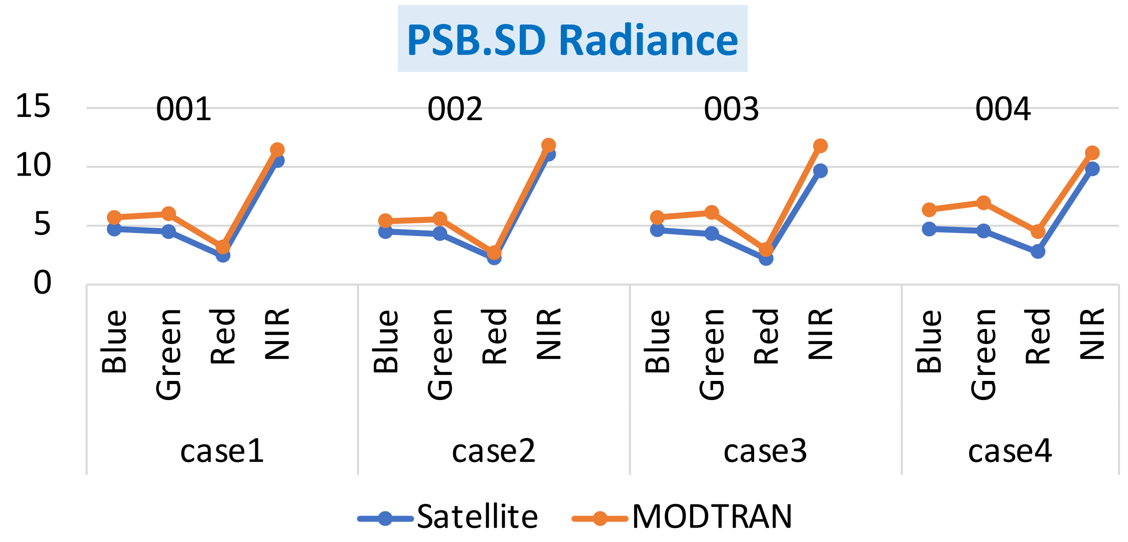


	Band 1	Band 2	Band 3	Band 4	Band 5
Satellite pixel	6.354	5.991	3.395	7.686	11.659
Modtran simulation	6.349	5.912	3.746	7.811	11.793
Difference (Satellite - Modtran)	0.005	0.079	-0.351	-0.125	-0.134
Difference (%) (Difference/ Modtran)	0.077%	1.338%	-9.372%	-1.604%	-1.133%

Comparison of simulated MODTRAN and Satellites (TOA)



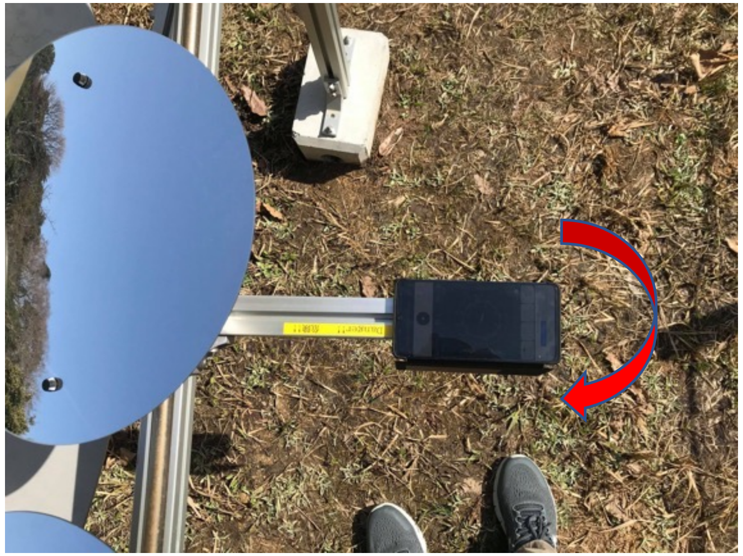




Characteristics of YUCARS’s Mirror Array

In according to the YUCARS’s tasking and scheduling for satellite observation, the mirror reflectors have been set up by adjusting a precise azimuth and tilt angles to get maximum reflectance from the mirrors.

A key for tilt angle adjustment

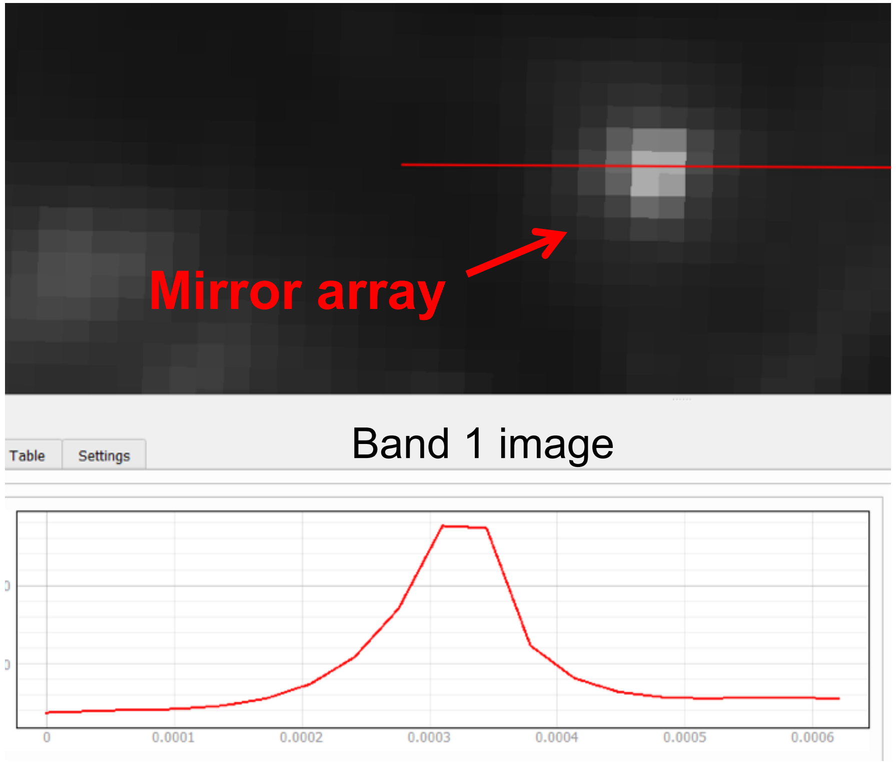


A key for azimuth angle adjustment

Mirror reflectors after adjustment

Observation of Mirror Array by GRUS-1A

2021-02-22



Pixel value

Image of Mirror Array

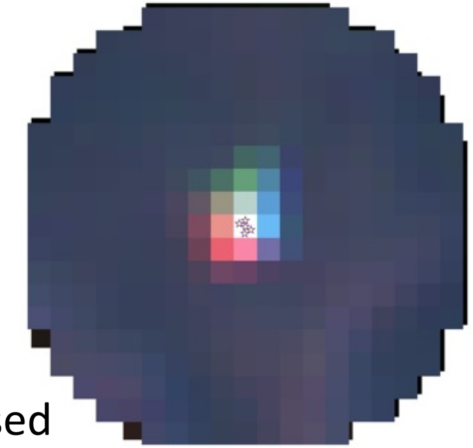
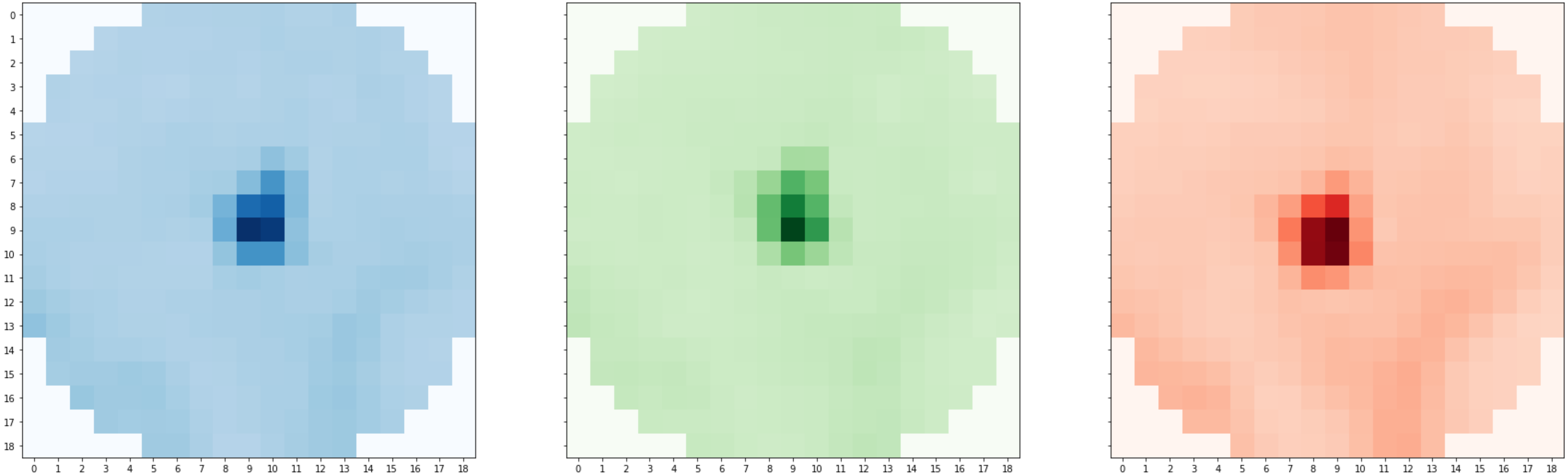


Image chip used

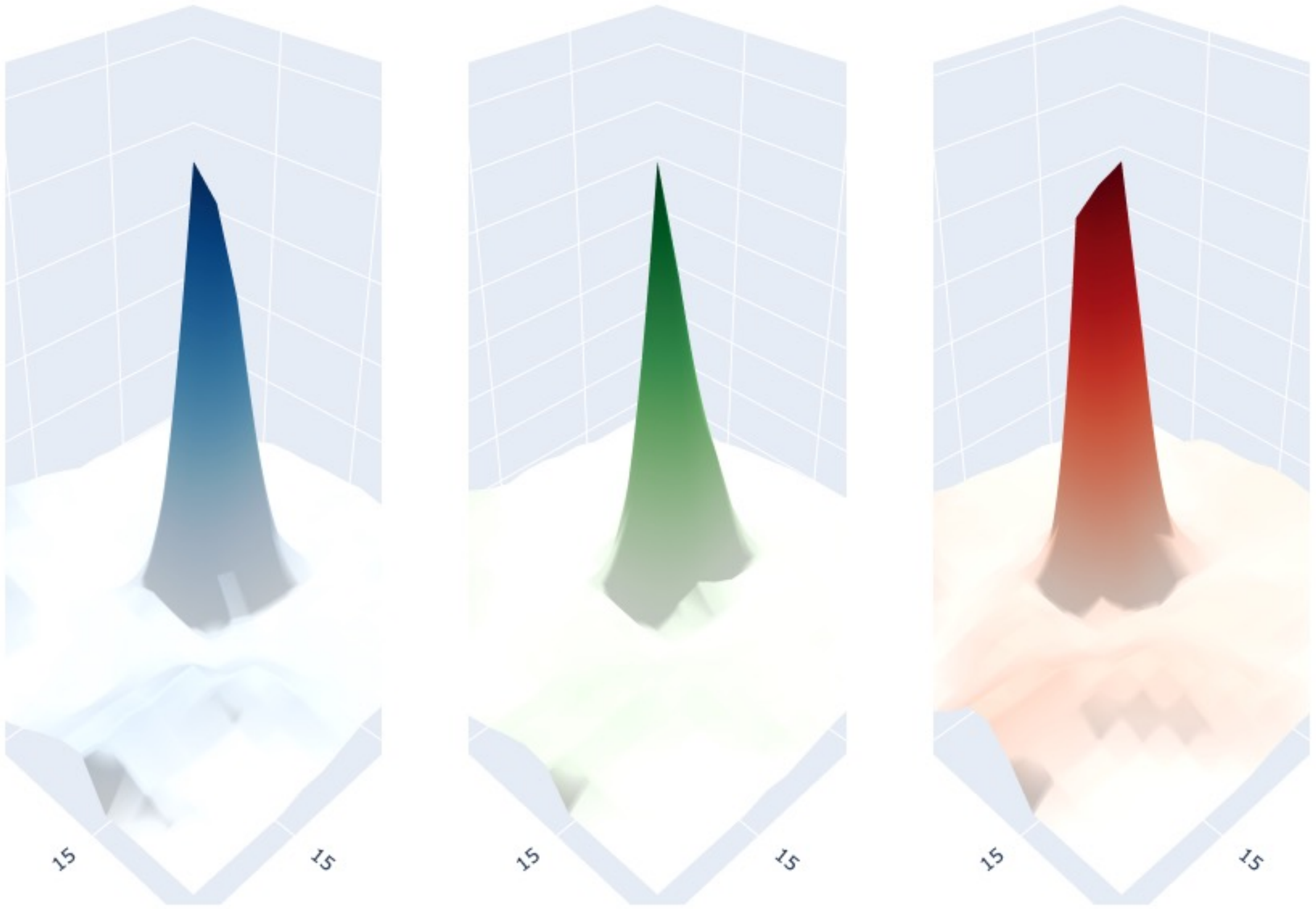


Energy Spread of Various Bands

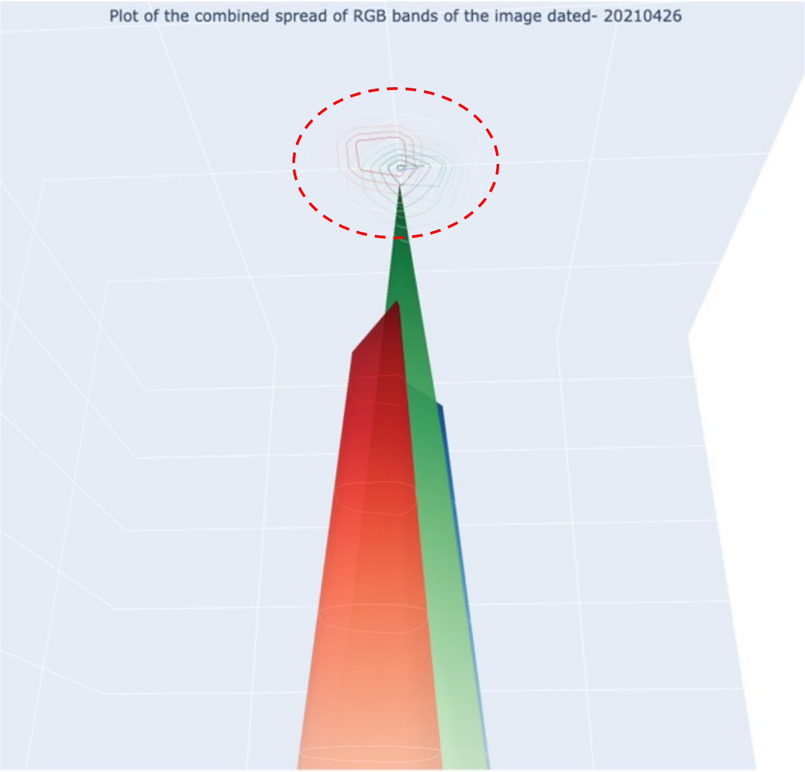
Energy distribution of each band is better as only single peak is visible in the plot.

Among all three bands, Green band performance is best, while the red band has worst.

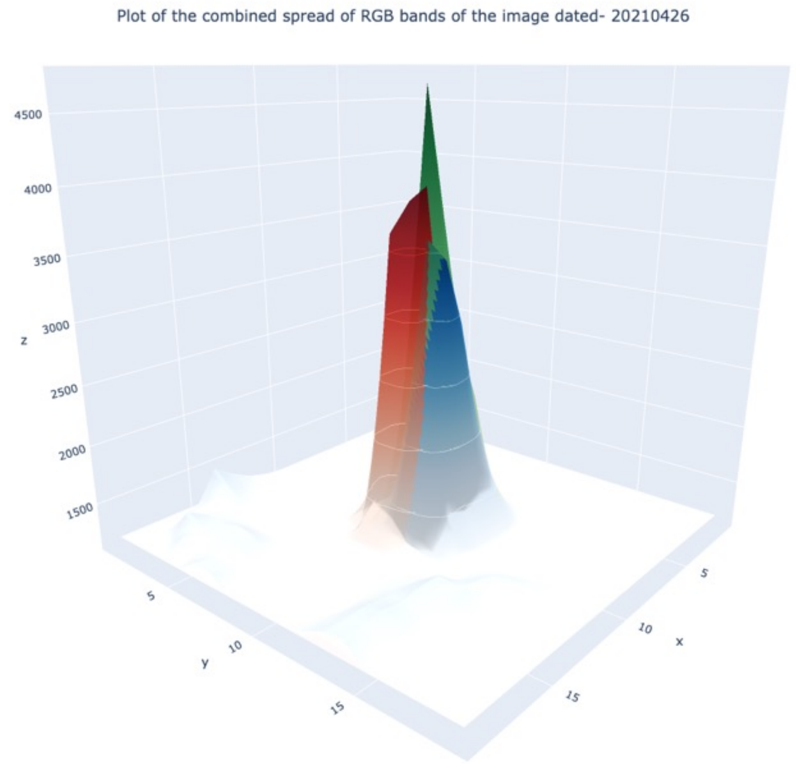
Plots of the seperate bands of the GRUS dated - 20210426



Energy Spread of Plot of Bands Together



Contour lines



Side perspective

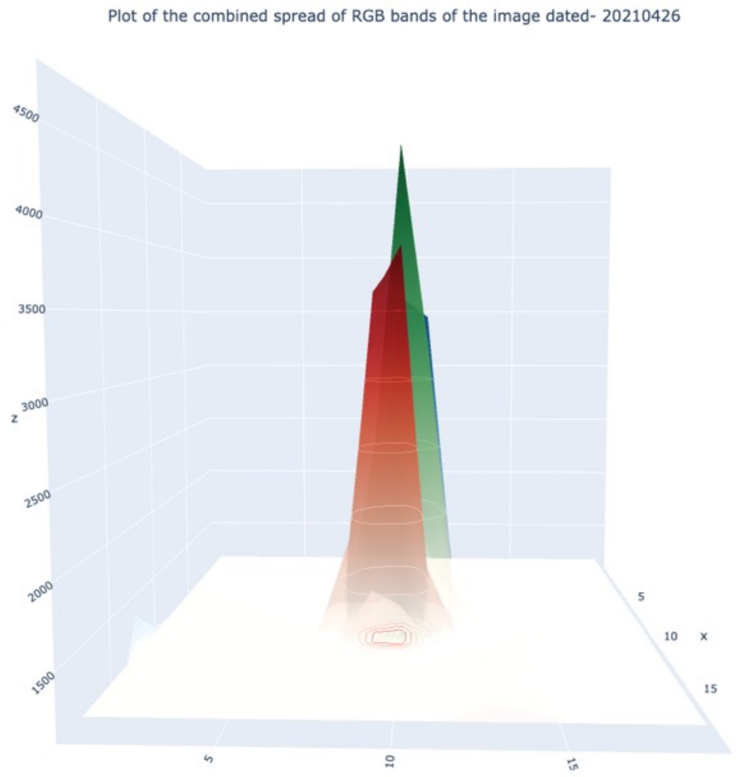
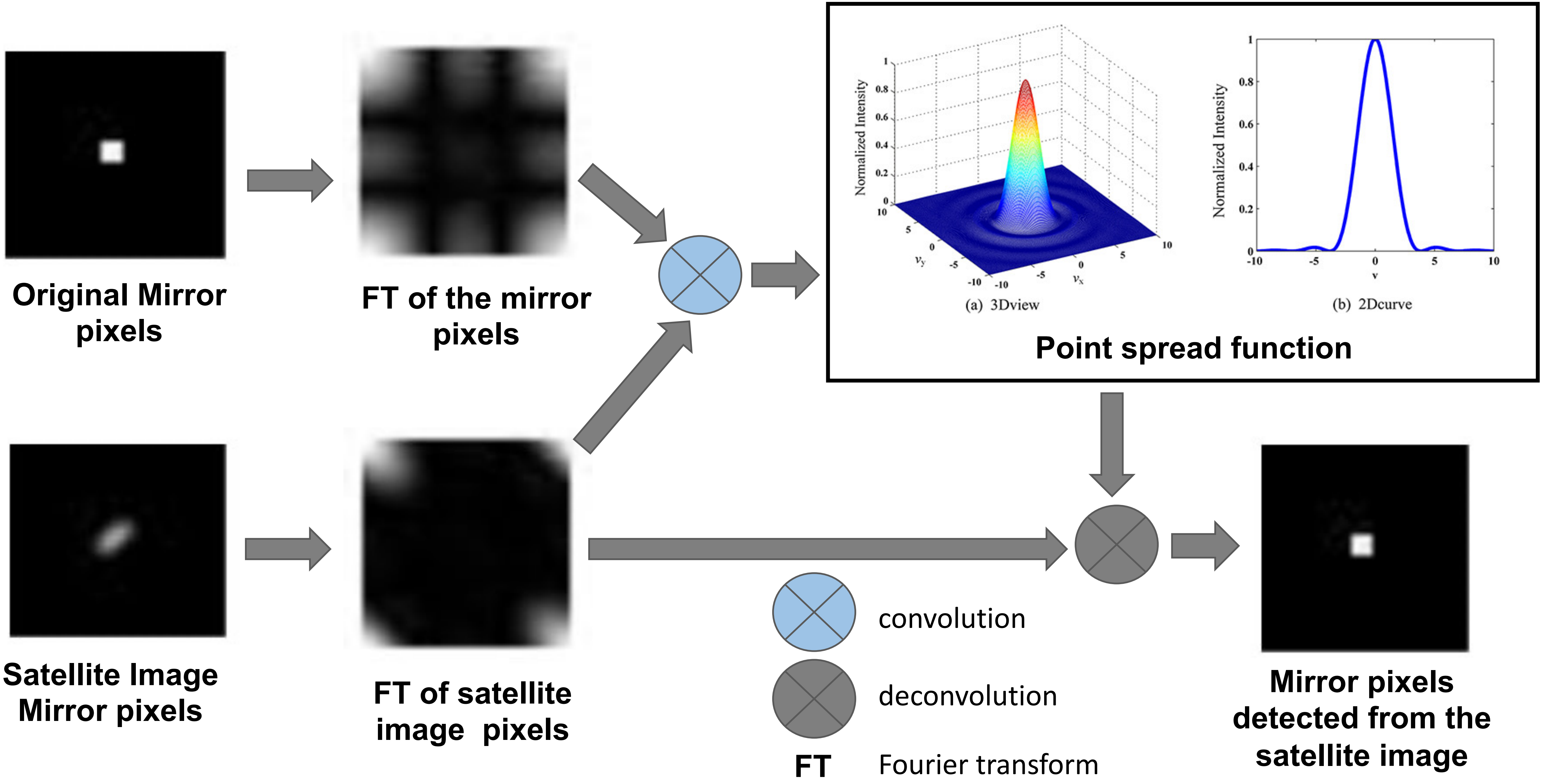


Image perspective

Concept of PSF (Point Spread Function) Calibration

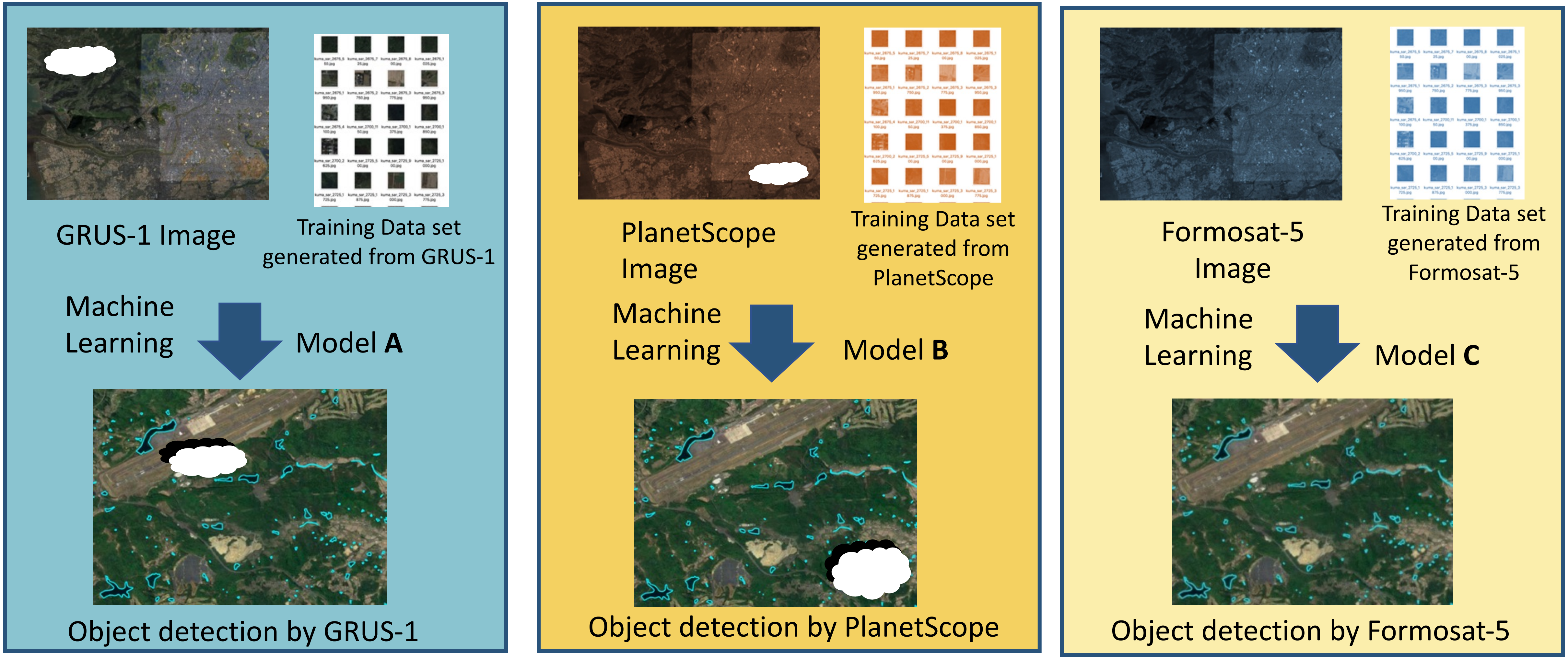


PSF for Image Reconstruction by Removing Distortions

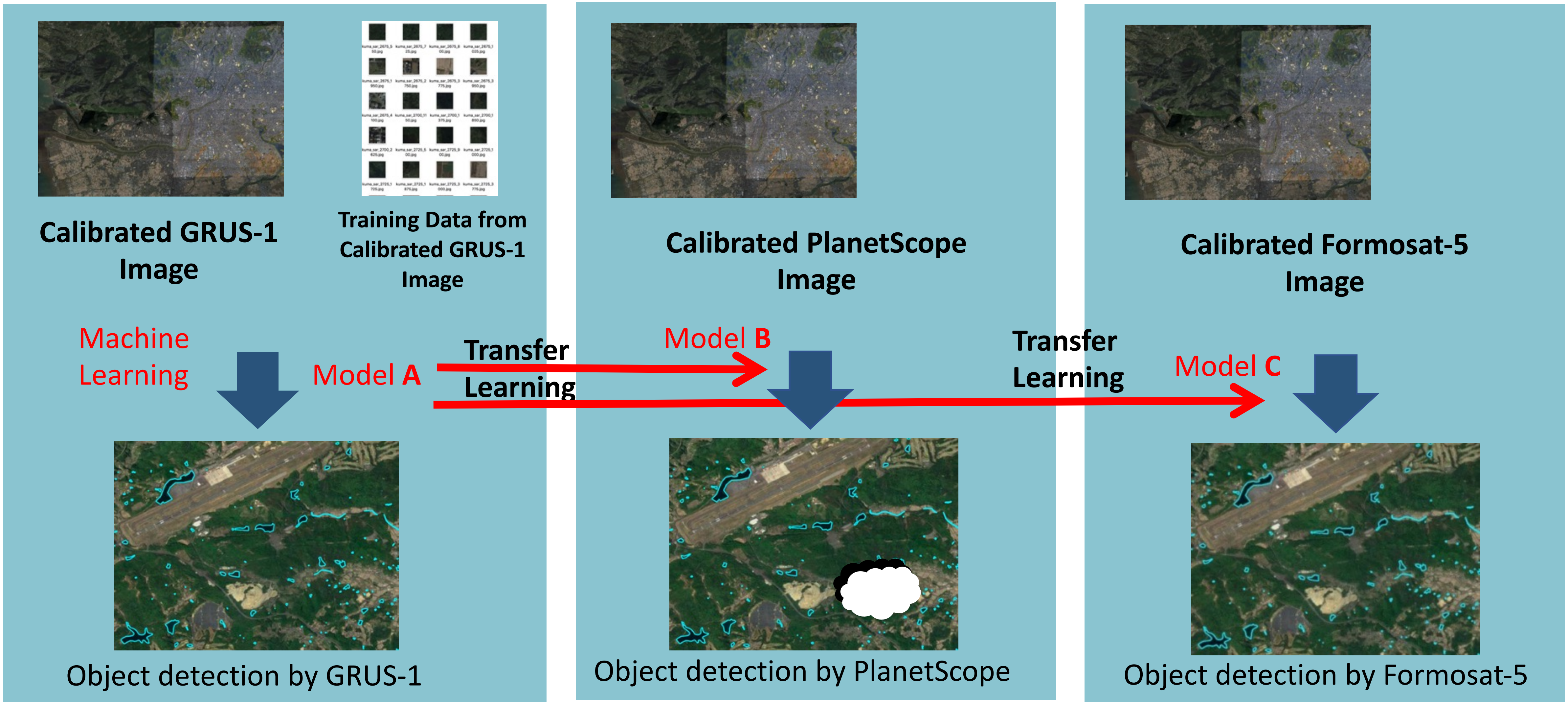
The original RGB image
(blurred source image

The blind deconvolved image using the PSF
(deblurred image)

Former Machine Learning for Satellite image



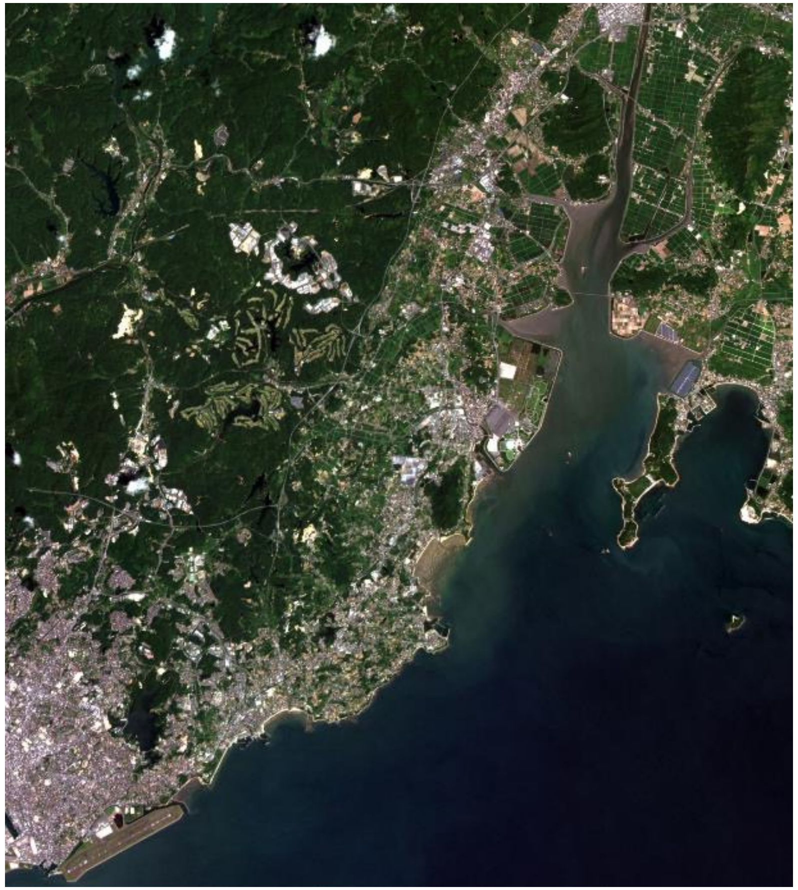
Transfer Learning with Calibrated Satellite image



Summary

1. Yamaguchi Univ. demonstrates convex mirrors calibration sites, which is called mirror array target.
2. This site consisting of mirror array as point source has been established and it allows to apply mirror technology different than traditional method.
3. The analysis shows radiometric performance and spread of reflected energy from the mirror center for the individual bands.
4. This site is used to construct point spread function (PSF) which has a strong potential to improve image quality by deblurring and defocusing techniques.

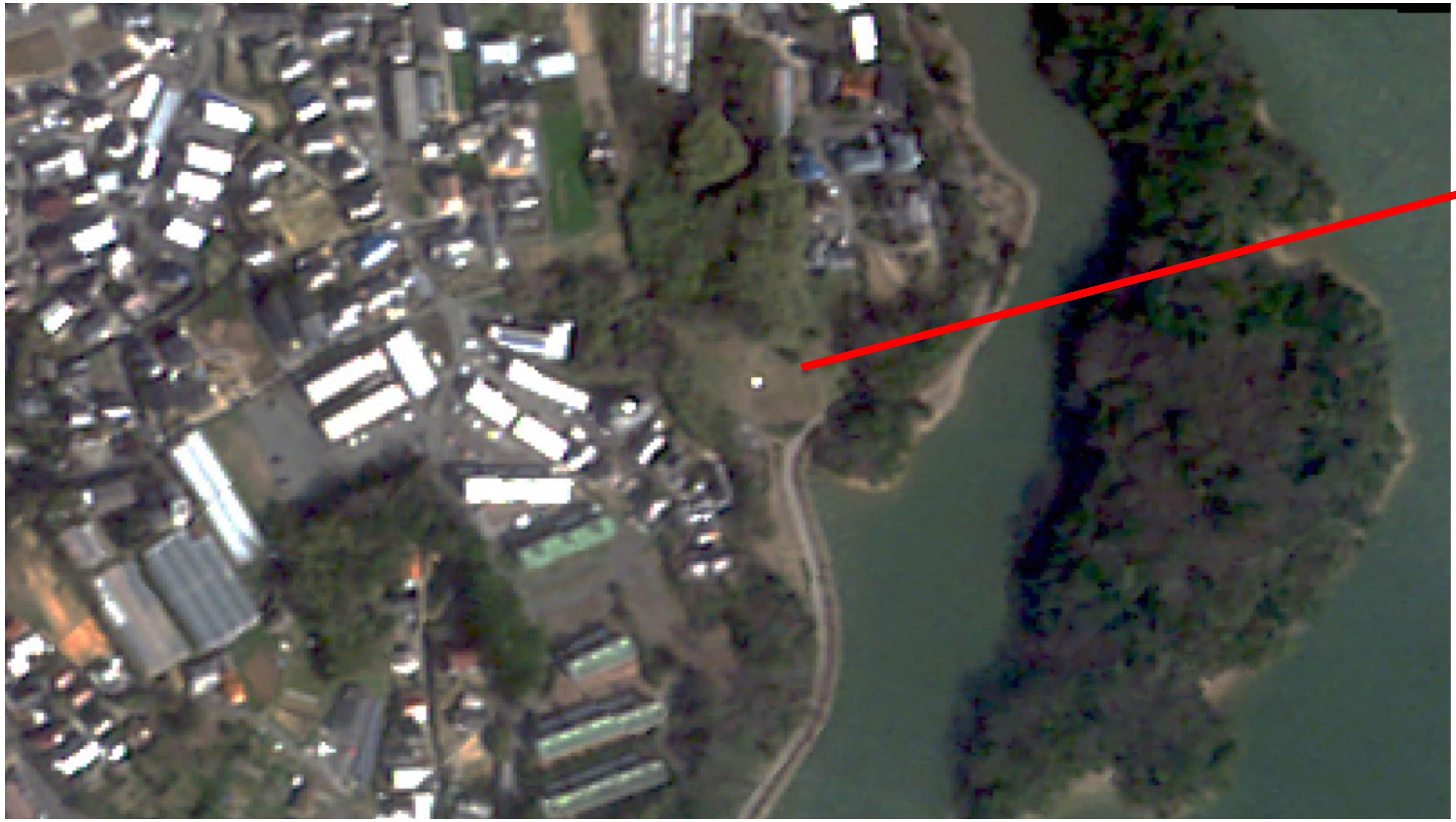
Observation of Mirror Array



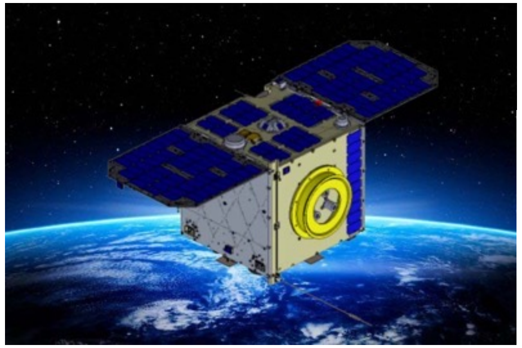
AXELSPACE

planet.

Observation of Mirror Array by Cartosat 2E



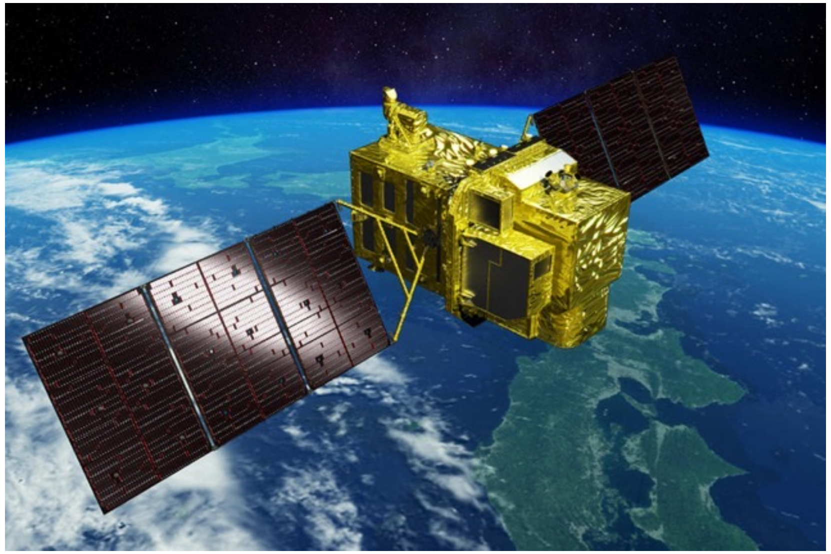
Next Observation Plan for Mirror Array



DIWATA-2

Philippine Space Agency

October 20 Capture – SMI



ALOS-3

Research Announcement on the Earth Observations: EO-RA3

NSPO

Thank you for your kind attention

YAMAGUCHI UNIVERSITY