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Prisma4sen2like: a spectral aggregation tool to transform PRISMA L1 hyperspectral data into Sentinel-2 PRISMA multispectral data

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4: CS Group, 5: RHEA Group, Italy,
6: European Space Agency

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Outline

1. Sen2like overview and status
2. PRISMA mission
3. PRISMA integration approach : prisma4sen2like
4. Spectral Aggregation details
5. PRISMA vs Sentinel-2 Geometry
6. Results

1. Sen2like overview and status

Purpose: The main goal of Sen2Like is to generate Sentinel-2 like harmonised/fused surface reflectances with higher periodicity by integrating additional compatible optical mission sensors.

Current missions supported: S2A, S2B, Landsat-8, Landsat-9

Effort to integrate a hyperspectral mission: PRISMA

The Sen2Like framework is a scientific and open source software.

Version 4.4 available since 2nd of August 2023: https://github.com/senbox-org/sen2like

Dedicated poster at S2VT6:

Sen2Like : A solution for harmonization and fusion of Sentinel-2 and Landsat 8/9 data
S. Saunier (Telespazio France)

1. Sen2like overview and status

2. PRISMA mission

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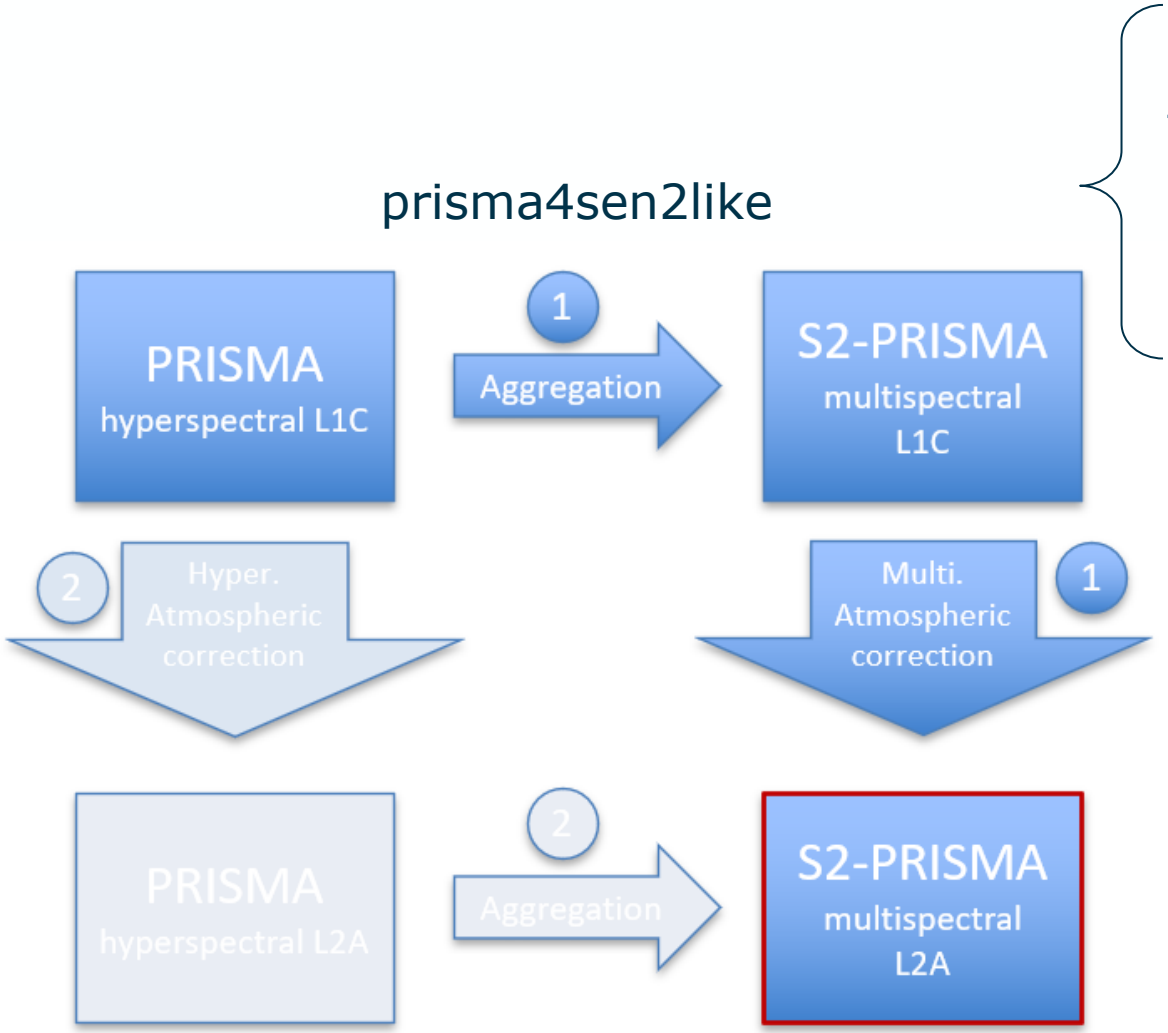
PRISMA is a medium-resolution hyperspectral imaging satellite, developed, owned and operated by ASI (Agenzia Spaziale Italiana)

Launched on 22 March 2019

Planned mission duration of 5 years.

Parameter	VNIR channel	SWIR channel	Pan channel
Spectral range	400–1010 nm	920–2505 nm	400–700 nm
Spectral resolution (FWHM)	≤ 12 nm	≤ 12 nm	–
Spectral bands	66	171	1
Swath width		30 km (FOV = 2.45°)	
Spatial resolution	30 m		5 m
Spatial detector pixels	1000 x 256 with 30 µm pitch		6000
IFOV	48.34 µrad		
Telescope type	TMA (Three Mirror Anastigmat)		
Telescope aperture	210 mm entrance pupil diameter		
Telescope focal length	620 mm		
Data quantization	12 bit		
FOR (Field of Regard)	±15° (body pointing capability)		

3. PRISMA integration approach



Spectral Aggregation (Hyperspectral to Multi spectral, 239 bands => 13 bands)

Geometric Processing: Projection (L1 -> L1C) + MGRS Reframing

Sen2like
Sen2cor 3.1 or SMAC

3. PRISMA integration approach

Prisma4sen2like:

- *Solar irradiance (Esun)*
- *Sun-Earth distance formula from Sentinel-2 mission*

Native L1 PRISMA → **Spectral Aggregation in radiance** (W.m-2.sr-1.µm-1) from 239 hyper-bands towards 13 multi-bands → Conversion from radiance (W.m-2.sr-1.µm-1) towards **TOA reflectance** (unitless) → **Projection into UTM** using Prisma L1 geocoding information => **L1C S2P** 13 multi-bands → **Internal L1C S2 PRISMA (S2P)**

L1 Sensor Geometry (S2-PRISMA) in radiance

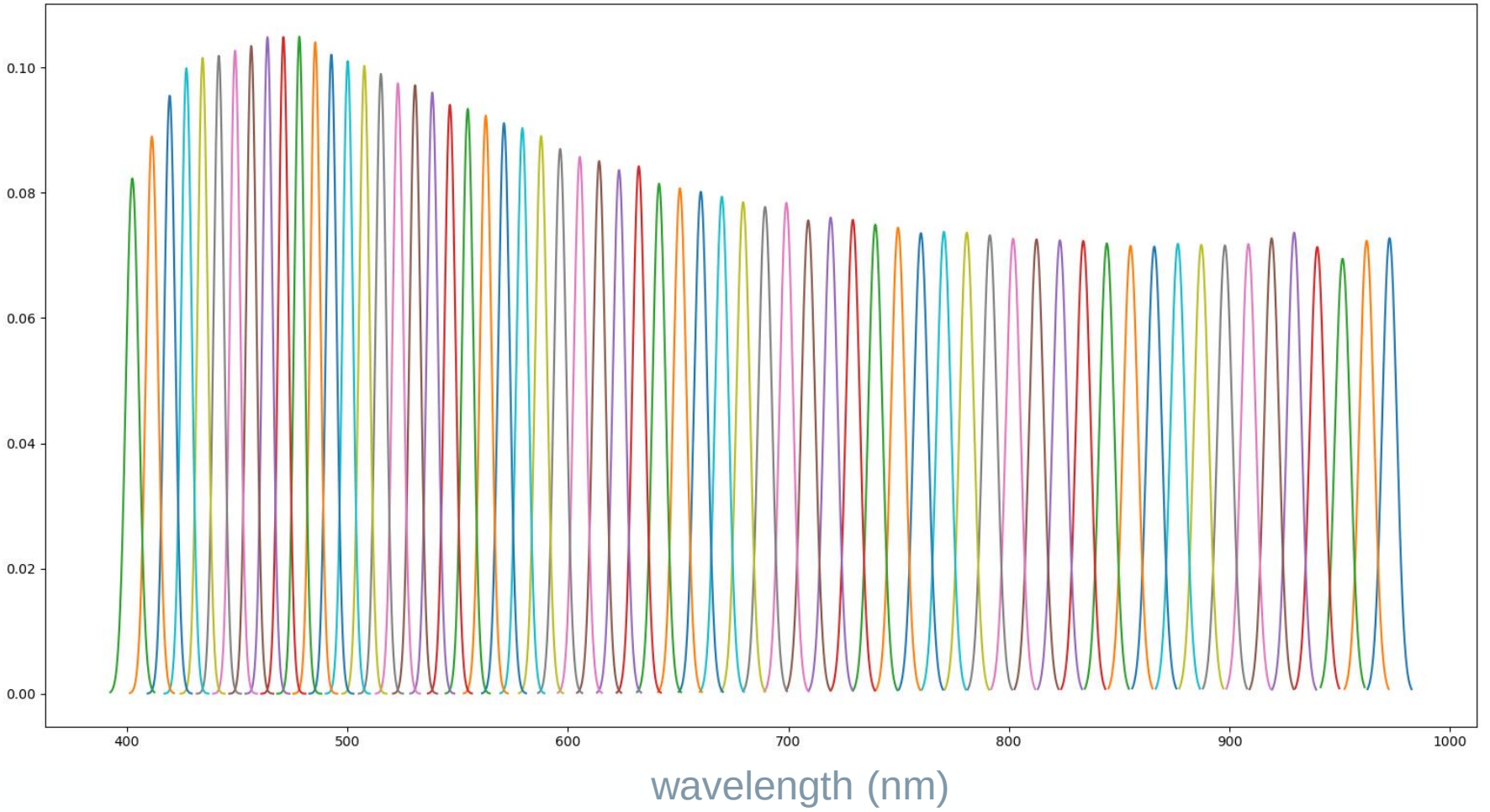
L1 Sensor Geometry (S2-PRISMA) in reflectance

L1C 33TTG TCI (S2-PRISMA)

4. Spectral Aggregation details

PRISMA spectral response of L1 coregistered images:

Same central wavelength (cw) and fwhm for all pixels across-track (smile and keystone corrected)

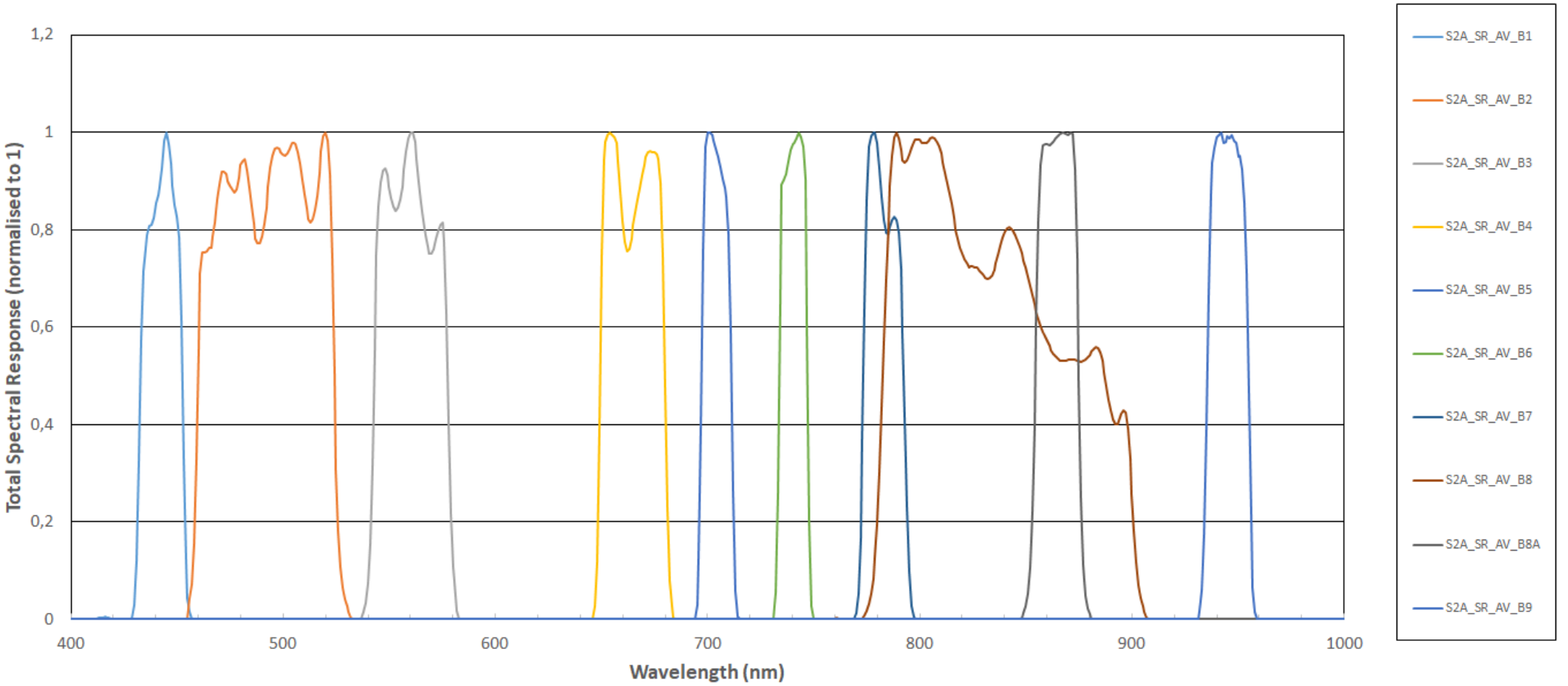


VNIR channels:

- 66 bands
- cw and fwhm read from L1 product metadata
- Assumption of gaussian shape of the spectral response

4. Spectral Aggregation details

Sentinel-2A spectral response (VNIR):



https://sentinels.copernicus.eu/documents/247904/685211/S2-SRF_COPE-GSEG-EOPG-TN-15-0007_3.1.xlsx (June 2022)

4. Spectral Aggregation details

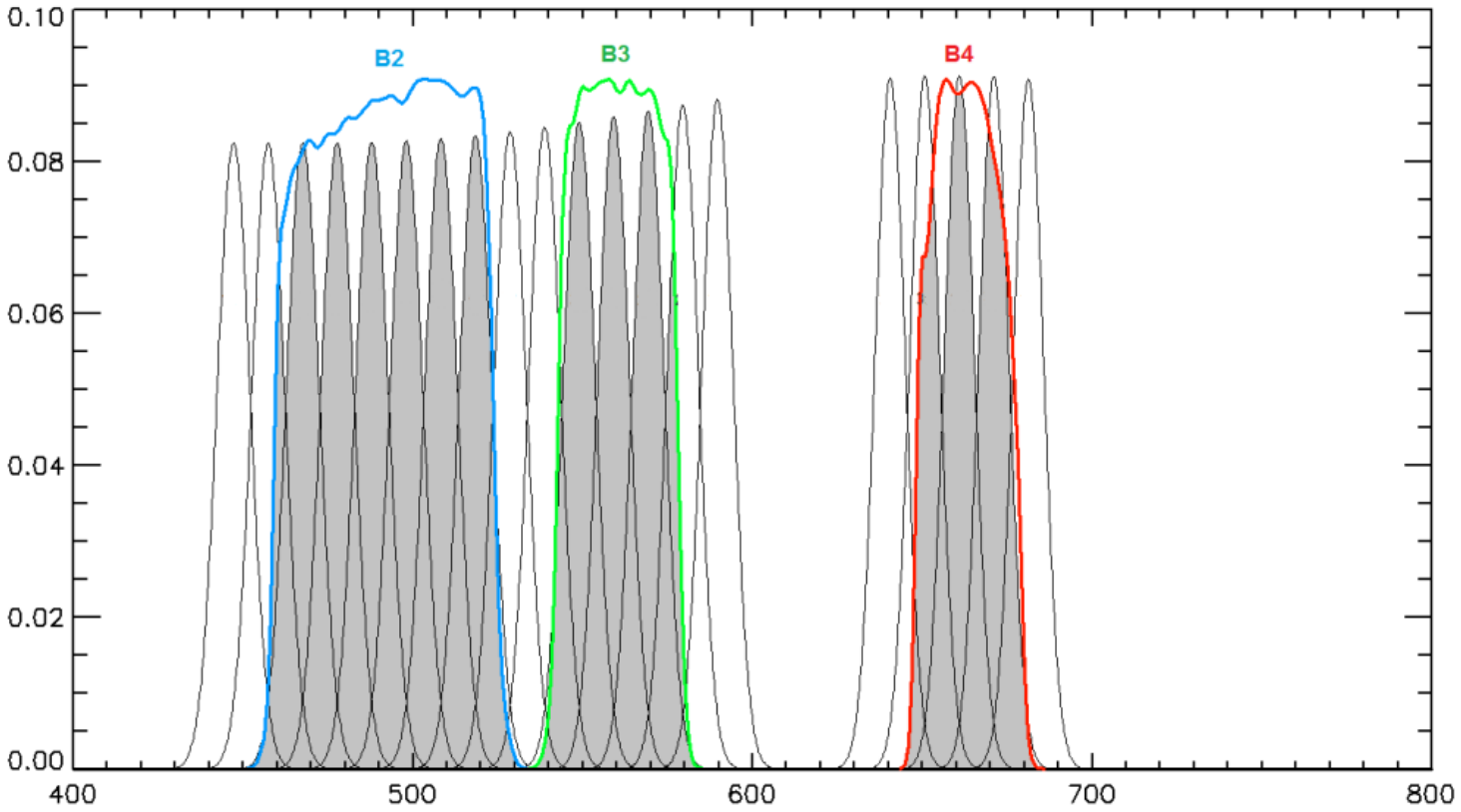
$$W_{xzb} = \sum_{k=z-15nm}^{K=z+15nm} G_{xzk} \times F_{kb}$$

$$P_{xzb} = \frac{W_{xzb}}{\sum_z W_{xzb}}$$

$$HB_{xb} = \sum_z P_{xzb} \times H_z$$

x : field of view location PRISMA ([0,1000]
z : PRISMA spectral band
k : spectral range interval
b : Sentinel-2 band
F : Sentinel-2A spectral response
G: PRISMA gaussian spectral response
W: unnormalized spectral weight for each PRISMA pixel
P: normalized spectral weight for each PRISMA pixel
H: Radiance value for each PRISMA pixel
HB: Aggregated Radiance for a Sentinel-2 band

PRISMA and Sentinel-2A of spectral responses (illustration)



- J. Louis, “Simulation of Sentinel-2 MSI multispectral images using EO-1 Hyperion hyperspectral data.”, Living Planet Symposium 2013
- P.S. Barry, et al,, “EO-1 Hyperion Hyperspectral Aggregation and Comparison With EO-1 Advanced Land Imager and Landsat 7 ETM+”. IGARSS 2002, Vol. III, 1648-1651.

5. PRISMA vs Sentinel-2 Geometry

Reference L1C
True Color Image
S2A acquisition
same day as
PRISMA acquisition

Colour composition:
RED: B04 [0-25%]
GREEN: B03 [0-25%]
BLUE: B02 [0-25%]

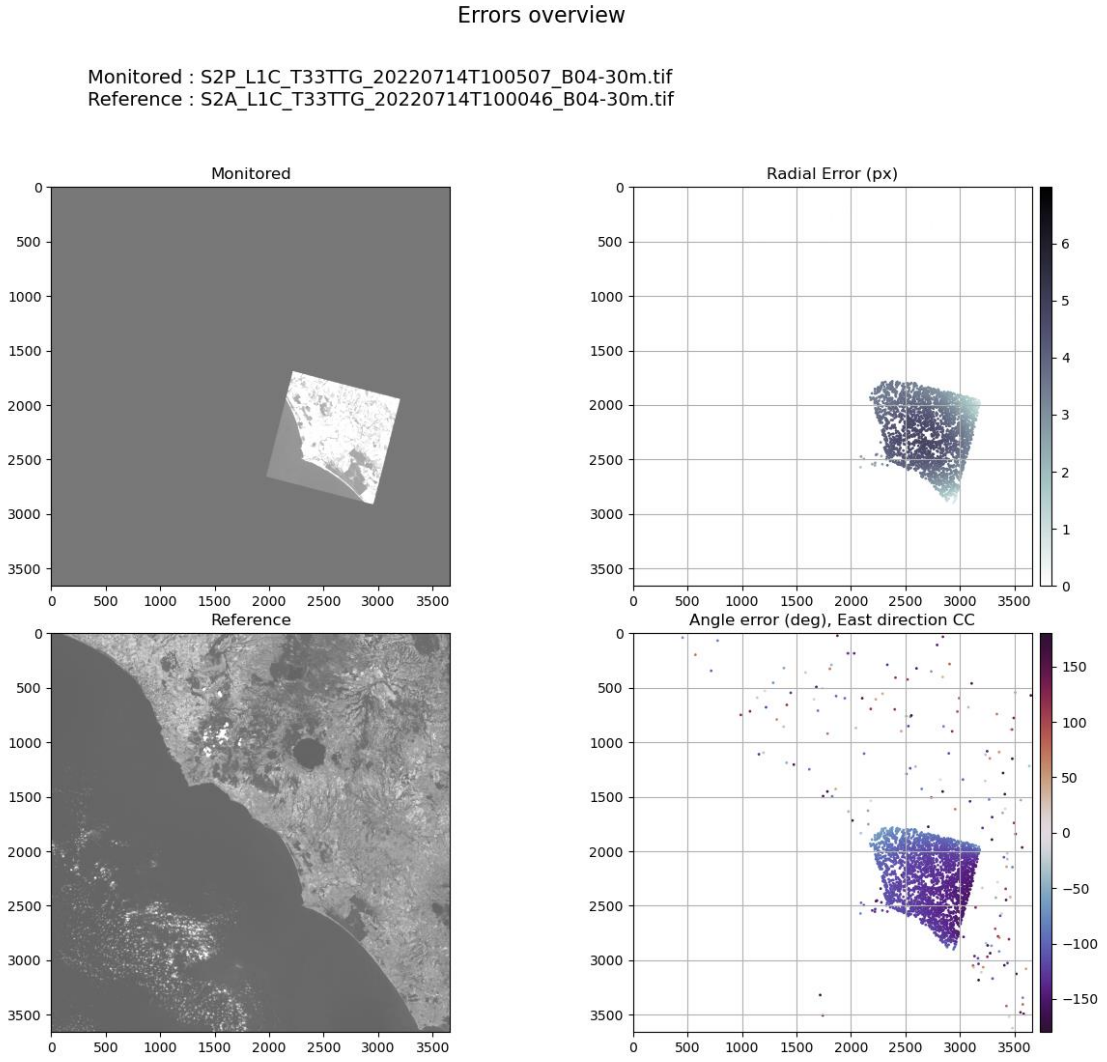
5. PRISMA vs Sentinel-2 Geometry

L1C S2-PRISMA
True Color Image
superimposed
on
Reference L1C
True Color Image
S2A

L1C TCI (S2A & S2-PRISMA)

Colour composition:
RED: B04 [0-25%]
GREEN: B03 [0-25%]
BLUE: B02 [0-25%]

5. PRISMA vs Sentinel-2 Geometry



Geometry assessment vs S2A

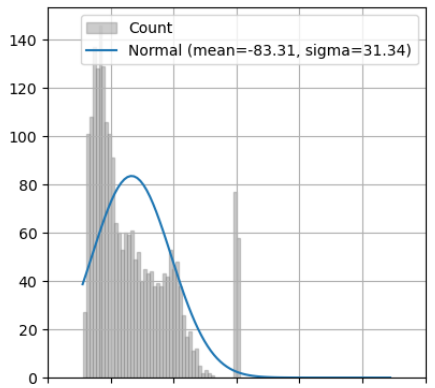
Results obtained with KARIOS tool. For details, see poster:

KARIOS : A fast & efficient open source tool
for geometric deformation analysis
S. Saunier (Telespazio France)

5. PRISMA vs Sentinel-2 Geometry

Geometric Error distribution

Monitored : S2P_L1C_T33TTG_20220714T100507_B04-30m.tif
Reference : S2A_L1C_T33TTG_20220714T100046_B04-30m.tif

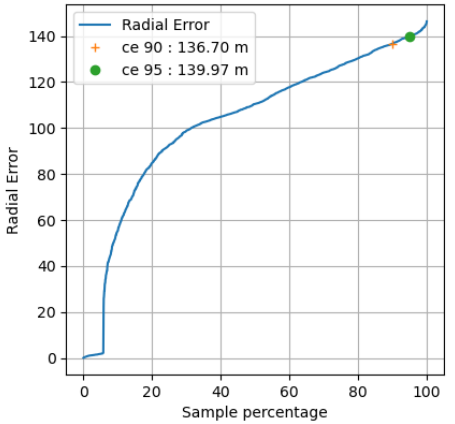


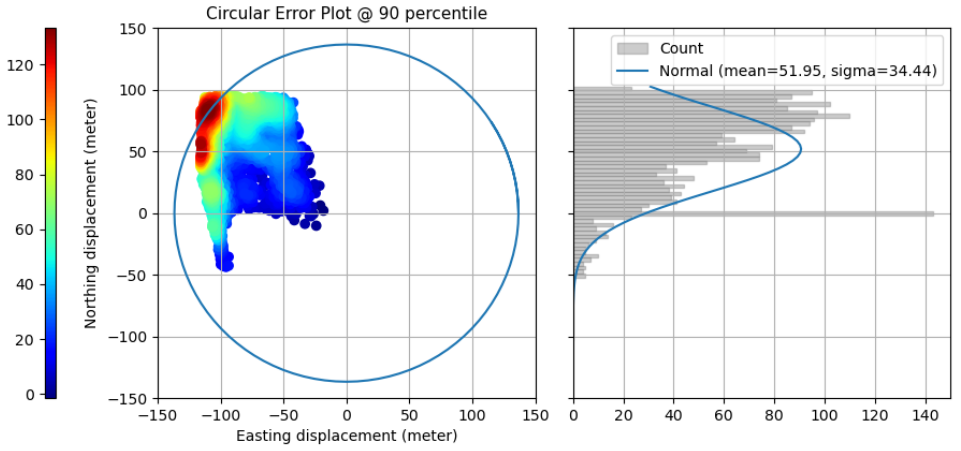
Total Number of Key Point : 2321
Confidence value : 0.40
Percentage of Confident Pixels : 0.02%
Pixel size : 30.0 m EPSG: 32633

Easting displacement (meter):
Min : -122.19 m
Max : 1.72 m
Mean : -83.31 m
Sigma : 31.34 m
RMSE : 89.01 m

Northing displacement (meter):
Min : -51.57 m
Max : 102.55 m
Mean : 51.95 m
Sigma : 34.44 m
RMSE : 62.32 m

Global RMSE : 108.66 m
CE @90 the percentile : 136.70 m
CE @95 the percentile : 139.97 m





Before geometric adjustment

Results obtained with KARIOS tool. For details, see poster:

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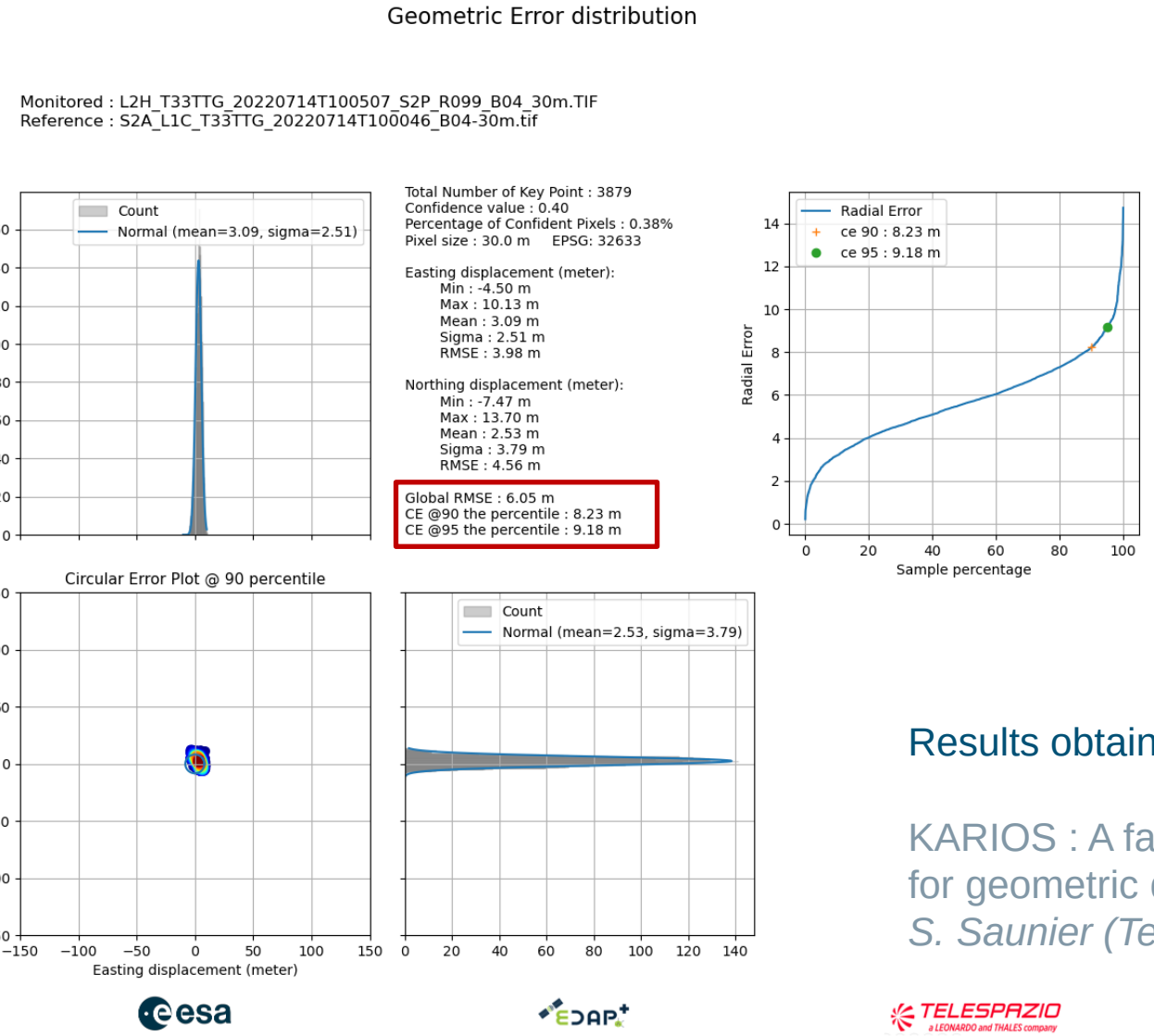
5. PRISMA vs Sentinel-2 Geometry



After geometric adjustment

Results obtained with KARIOS tool. For details, see poster:

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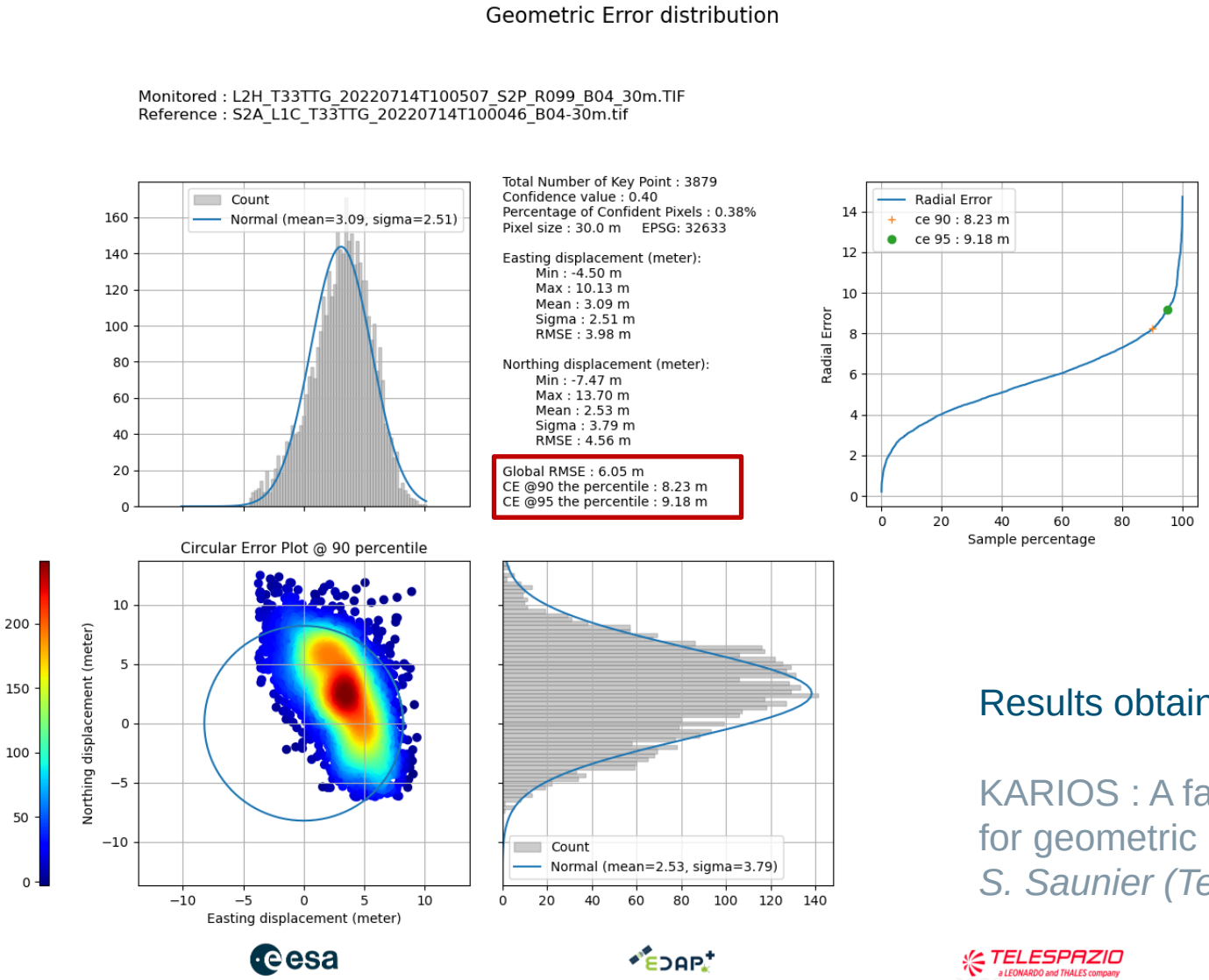
5. PRISMA vs Sentinel-2 Geometry



After geometric adjustment

Results obtained with KARIOS tool. For details, see poster:

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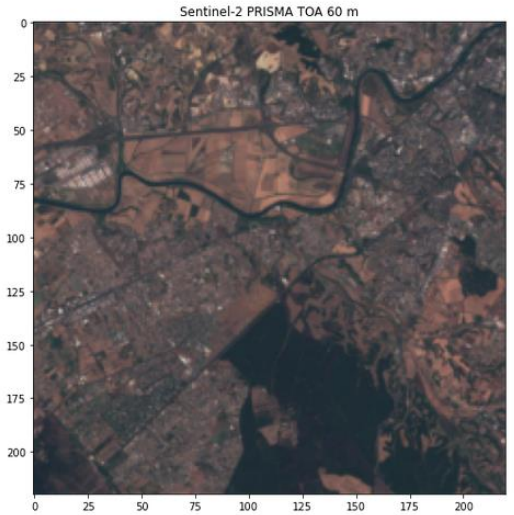
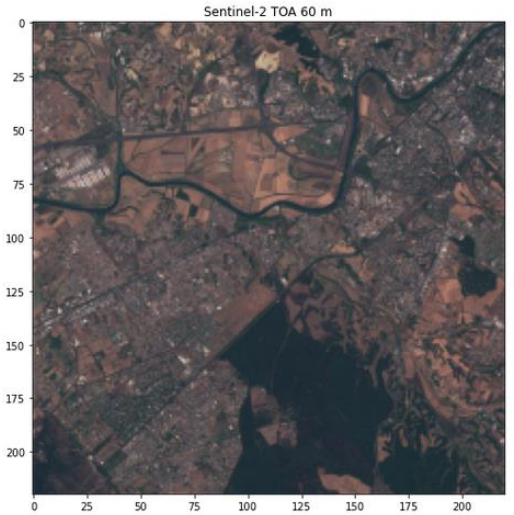
6. Results

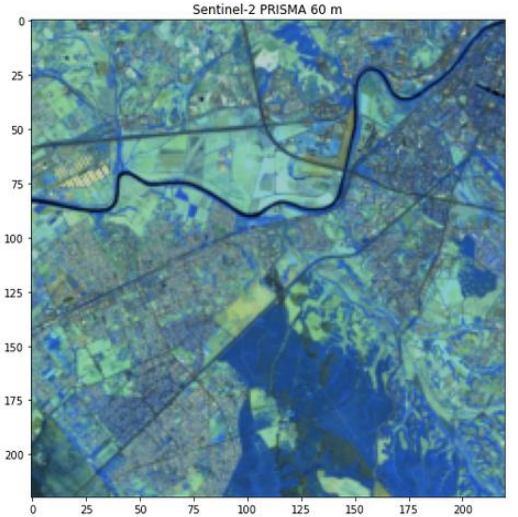
Sentinel-2 tile: 33TTG (Rome) 14th of July 2022

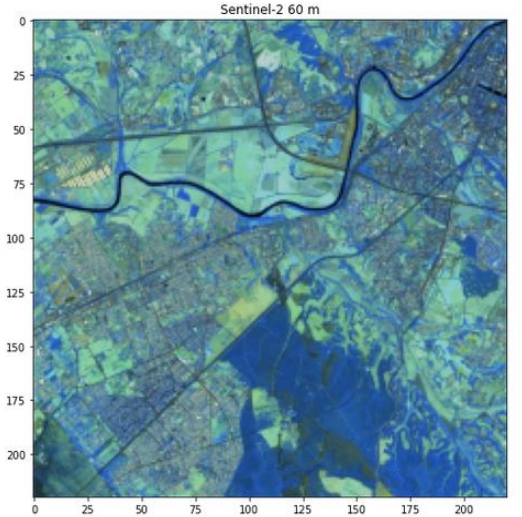




Visible (red = B04, green = B03, blue = B02)

S2A / PRISMA tandem acquisition (5 minutes difference)





NIR-SWIR (red = B12, green = B11, blue = B8A)

Sun illumination angles almost identical:

ZENITH_ANGLE: 24.8 deg

AZIMUTH_ANGLE: 139.5 deg

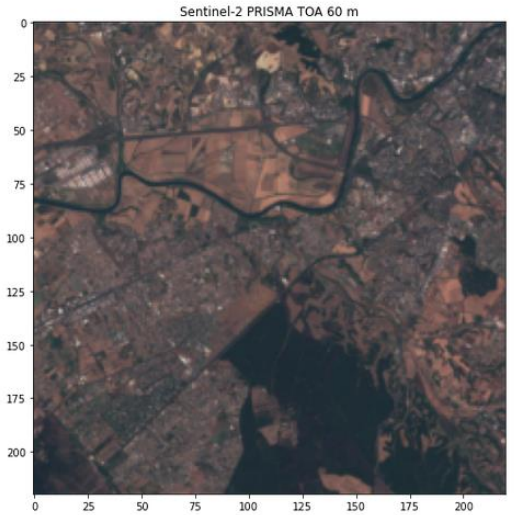
Similar viewing angles conditions:

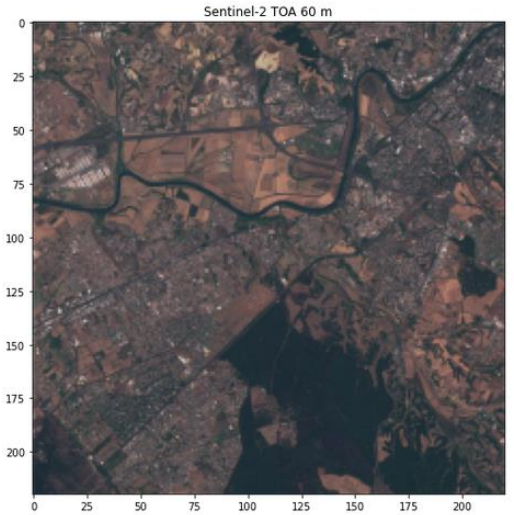
S2A: VZA ~ 8 deg ; VAA ~ 103 deg

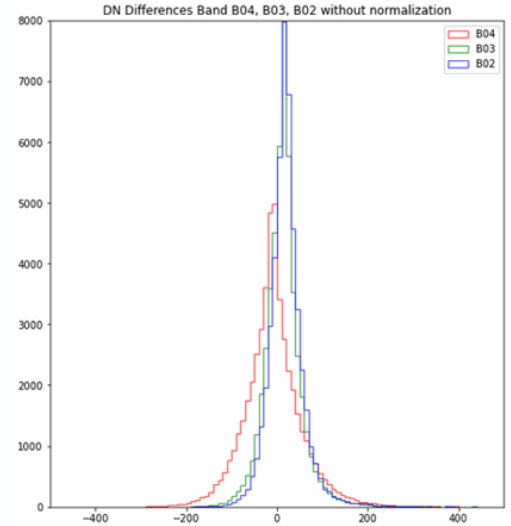
PRISMA: VZA ~ 4 deg ; VAA ~ 110 deg

6. Results

Sentinel-2 tile: 33TTG (Rome) 14th of July 2022







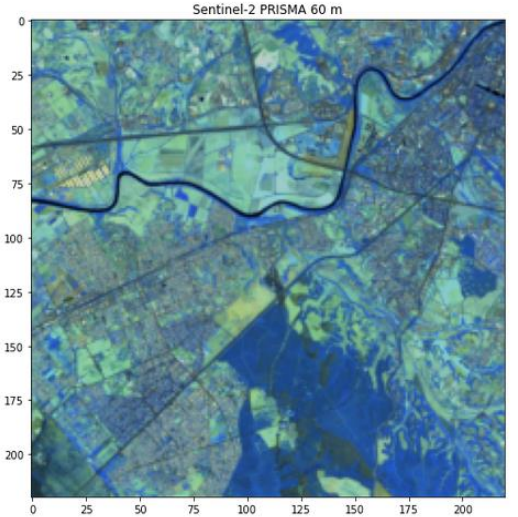
Histogram of the differences:
S2A – S2P

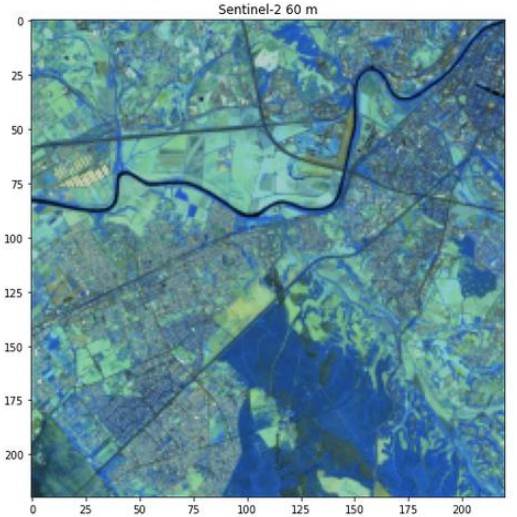
B02 (blue): mean: +0.9 %

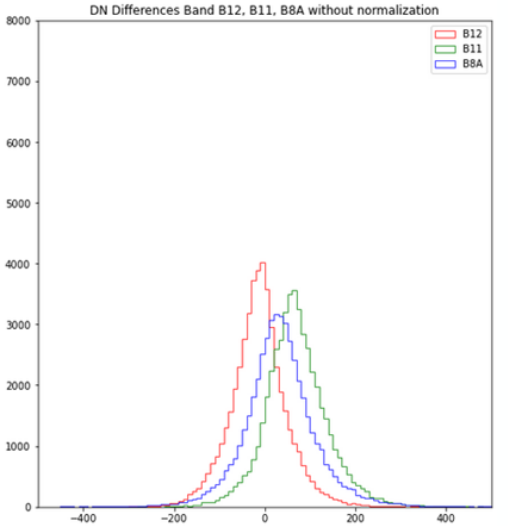
B03 (green): mean: +0.6 %

B04 (red): mean: -0.4 %

S2A / PRISMA tandem acquisition (5 minutes difference)







Histogram of the differences:
S2A – S2P

B8A (NIR): mean: +0.8%

B11 (SWIR 1): mean: +1.9%

B12 (SWIR 2): mean: -0.4%

Conclusions

The radiometric agreement of PRISMA mission with Sentinel-2A looks good at TOA reflectance, within 1% of mean difference except for B11 slightly brighter (+1.9 %) for S2A.

These results were obtained using the **prisma4sen2like** tool for spectral aggregation of PRISMA bands and a dedicated geometric correction within sen2like geometry block.

The prisma4sen2like tool is available within the Sen2Like framework, a scientific and open-source software at:

https://github.com/senbox-org/sen2like/tree/master/prisma4sen2like

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The views expressed herein can in no way be taken to reflect the official opinion of the European Space Agency or the European Union.

Thank you for your attention!