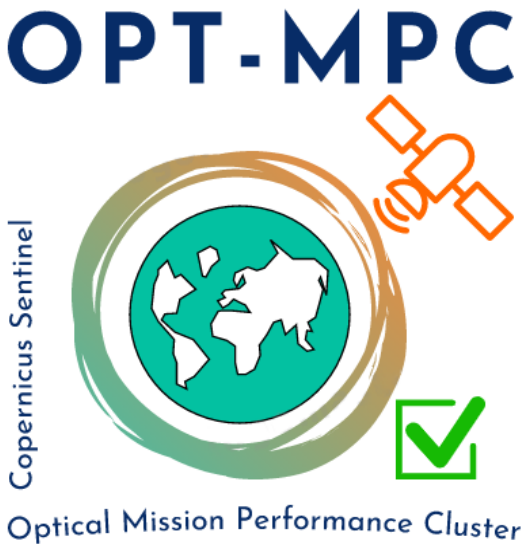


In-Orbit Radiometric performance of Sentinel-2/MSI: Inter-comparison with LANDSAT8/OLI-1 and LANDSAT9/OLI-2 over desert PICS using DIMITRI-toolbox

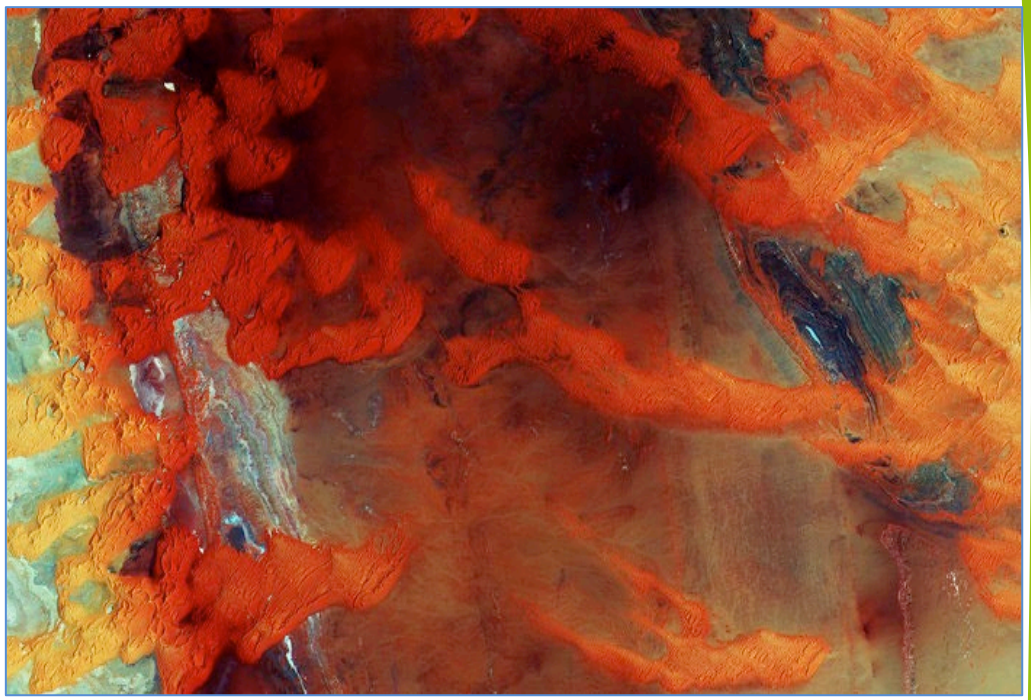
B. Alhammoud[1], C. Mackenzie[1], J. Jackson[1], S. Clerc[2], J. Bruniquel[2], B. Lafrance[3], S. Enache[3], R. Iannone[4], V. Boccia[5], M. Bouvet[6]

1) ARGANS Ltd, 2) ACRIS-ST, 3) CS Group, 4) Rhea Group, 5) ESA/ESRIN, 6) ESA/ESTEC

12 September 2022, CALCON2022

Agenda

- Dataset and Tools
- Sentinel-2 radiometry vicarious validation
- Sentinel-2A/B radiometry intercalibration
- Sentinel-2A/B and LANDSAT-8/9 Radiometry intercomparison
- Conclusion



Libyan dunes as seen by MSI-A
Credit: Copernicus Sentinel data (2015)/ESA, CC BY-SA 3.0 IGO

Datasets

17 CalVal sites for Sentinel-2 & 10 CalVal sites for Landsat8/9

Sentinel-2/MSI:
L1C: TOA reflectance + AUX-data
13 bands VNIR/SWIR
2015-present

LANDSAT/OLI:
L1TP: TOA reflectance + AUX-data
8 bands VNIR/SWIR
2013-present

CalVal sites available in DIMITRI-toolbox

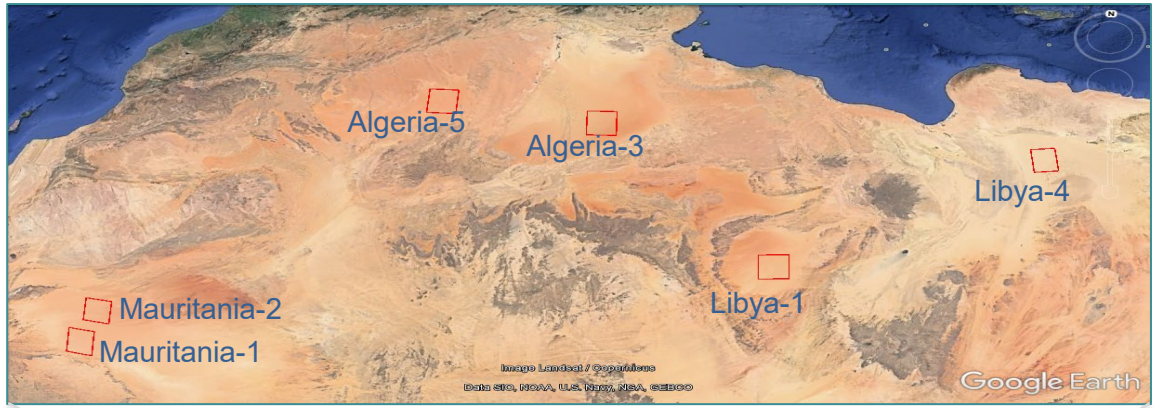
17 CalVal sites for Sentinel-2 &
10 CalVal sites for Landsat8/9

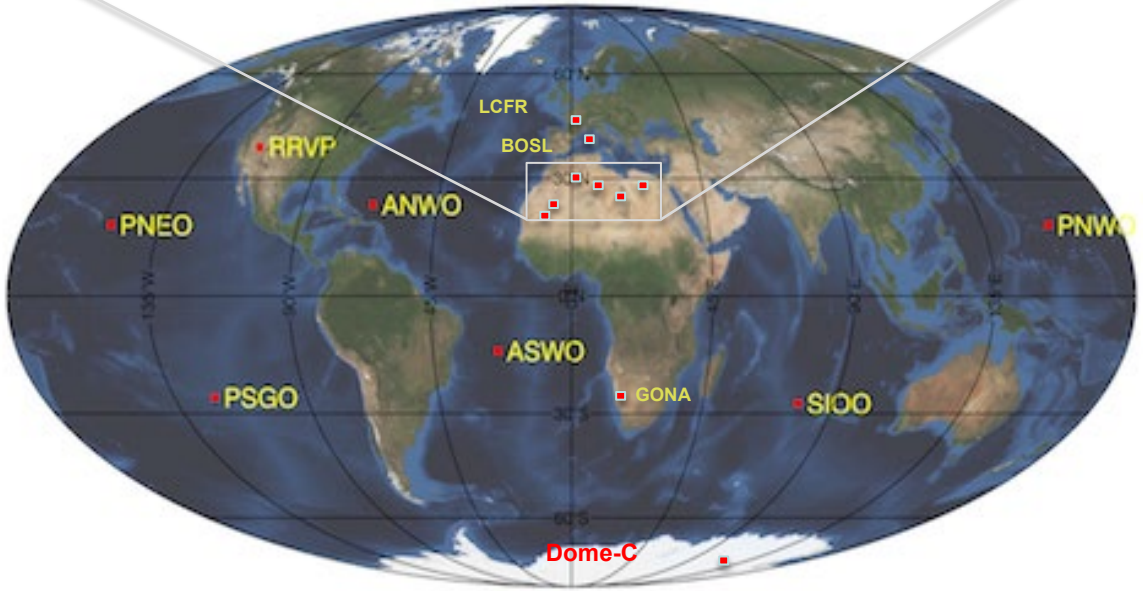
Bright sites:
Desert:
- 6 CEOS-PICS
- Gobabeb
- RRVP
- BSCN

Ice/Snow
- DOME-C

Dark sites:
Land:
- La Crau

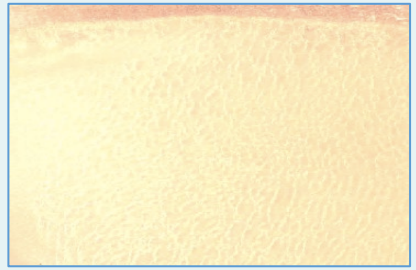
Water
- 6 Open Ocean
- Boussole (Costal)





Site type	Water	La Crau	Desert	Snow
Reflectance range	0-0.2	0.2-0.3	0.2-0.7	0.7-0.9

Vicarious Methods in DIMITRI-toolbox

Rayleigh scattering calibration	Sun-Glint inter-bands calibration	Desert (PICS) calibration	Sensor-to-Sensor intercalibration
			
Absolute calibration coefficient: as ρ^{obs}/ρ^{sim}	Absolute Inter-band calibration coefficient: as $\rho^{B(i)}/\rho^{B(ref)}$	Relative calibration coefficient: as ρ^{obs}/ρ^{sim} (MERIS as REF)	Absolute inter-calibration coefficient: as ρ^{obs}/ρ^{REF}
- Over VIS bands - Uncertainty <5% - Very stringent criteria	- Over VNIR bands - Uncertainty <2% - Very stringent criteria	- Over VNIR bands - Uncertainty <5% - Uses surface BRDF	- VIS, NIR & SWIR - Uncertainty <5% - Limited matchups

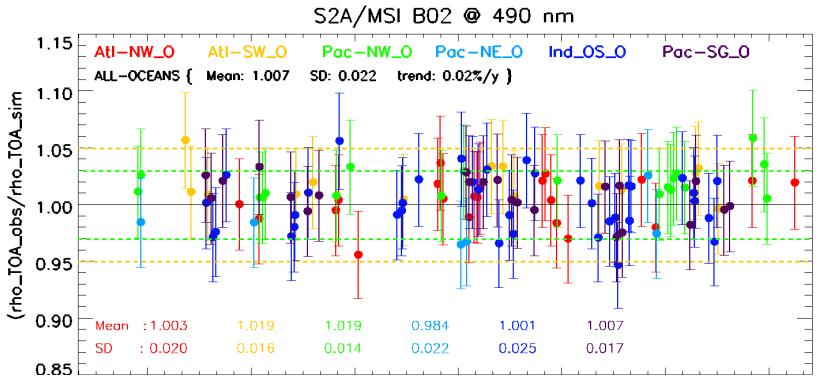
https://dimitri.argans.co.uk

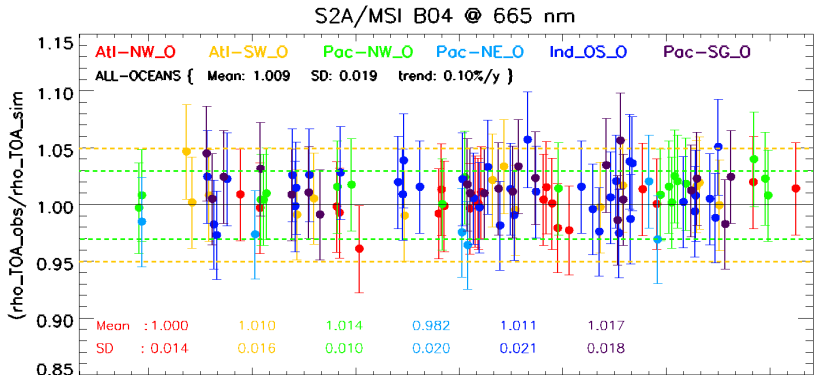
Absolute Radiometry Vicarious Validation

RAYLEIGH METHOD: 6 CalVal sites & time-series up to April 2022

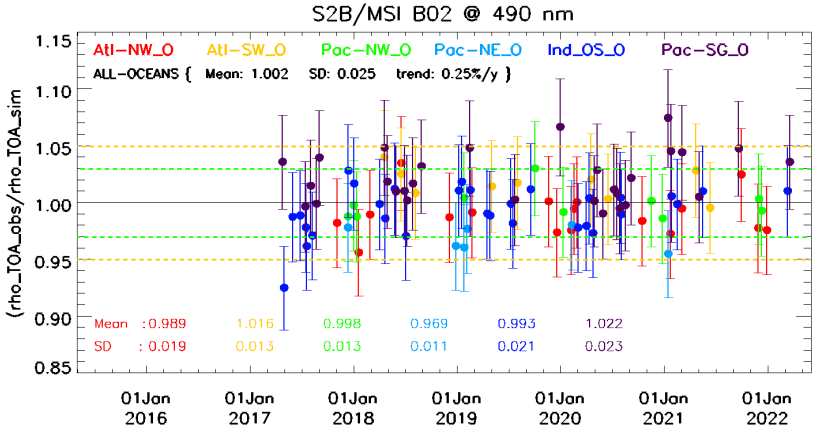
- **S2A/MSI**; 91 acquisitions used; **VIS are within 3%** ; **Except B01 (Software limitation)**
- **S2B/MSI**; 73 acquisitions used; **VIS are within 3%**

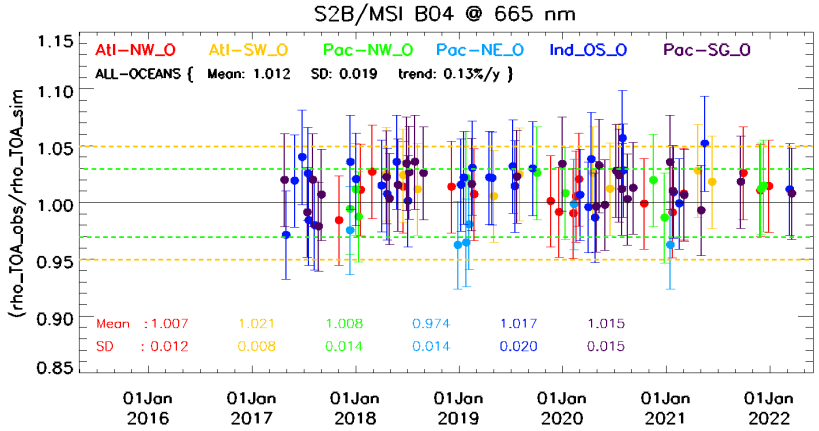
S2A/MSI





S2B/MSI



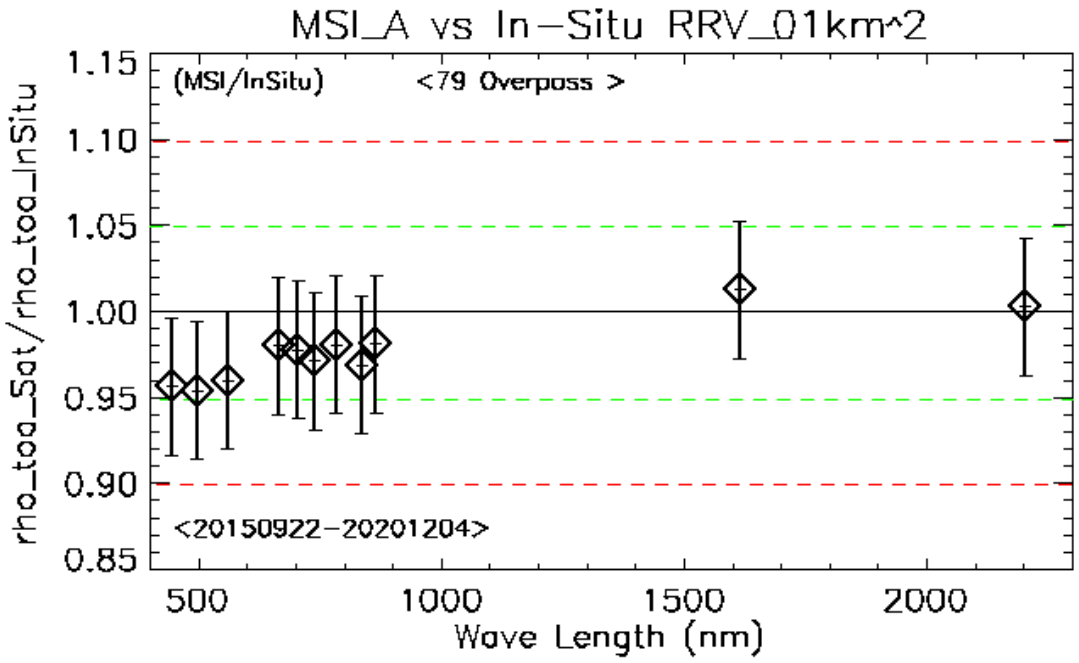


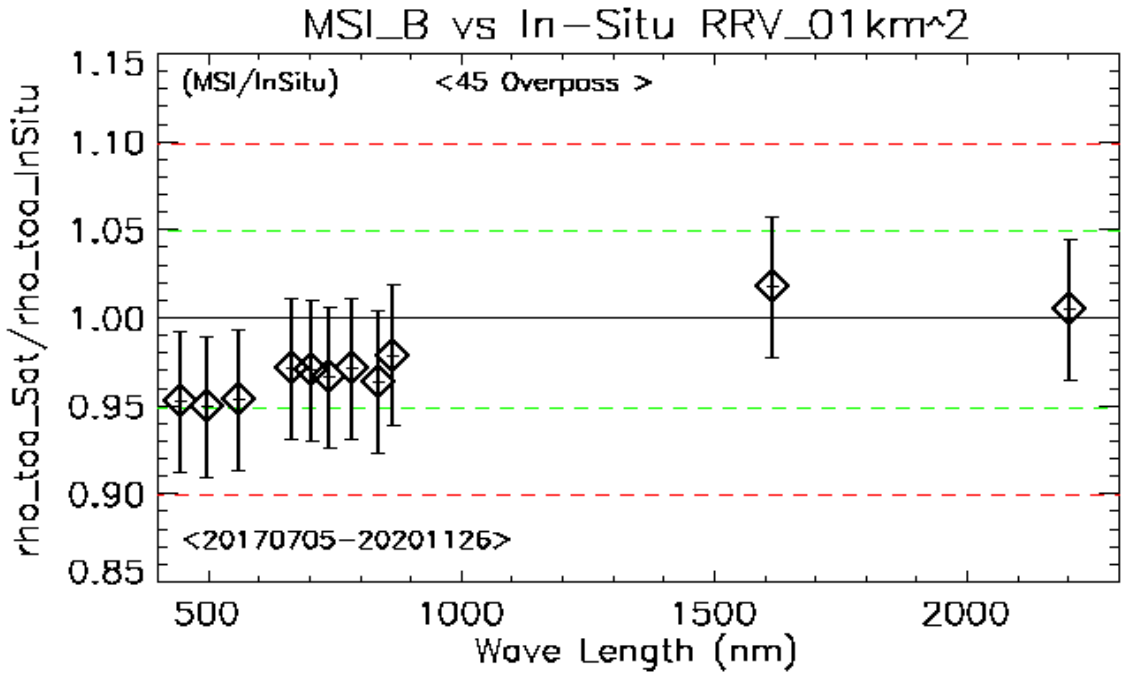
Wavelength (nm)	MSI-A	MSI-B
443	1.038	1.028
490	1.007	1.002
560	1.009	1.005
665	1.009	1.012

Absolute Radiometry Vicarious Validation

In-Situ measurements: over Railroad Valley (RadCaTS dataset) up to Dec. 2020

- Average over **79** overpasses S2A and **45** overpasses S2B
- ROI: 0.1°x0.1° latitude x Longitude
- All bands are within 5% (excluding B09, B10).





(RADCATS dataset were provided by the NASA Landsat Cal/Val Team as part of the ESA expert users effort)

Absolute Radiometry Vicarious Validation

In-Situ measurements: over RadCalNet dataset up to May. 2022: (TOA reflectance, NADIR-view)

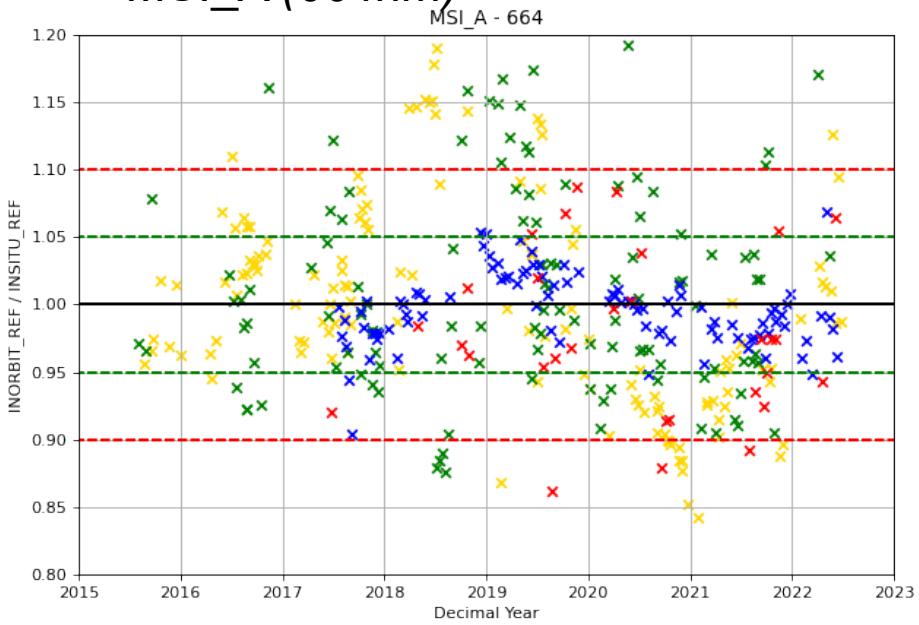
- **About 400** overpasses **S2A** and **350** overpasses **S2B**
- ROI: 0.1°x0.1° latitude x Longitude
- Interannual variability.
-

RadCalNet

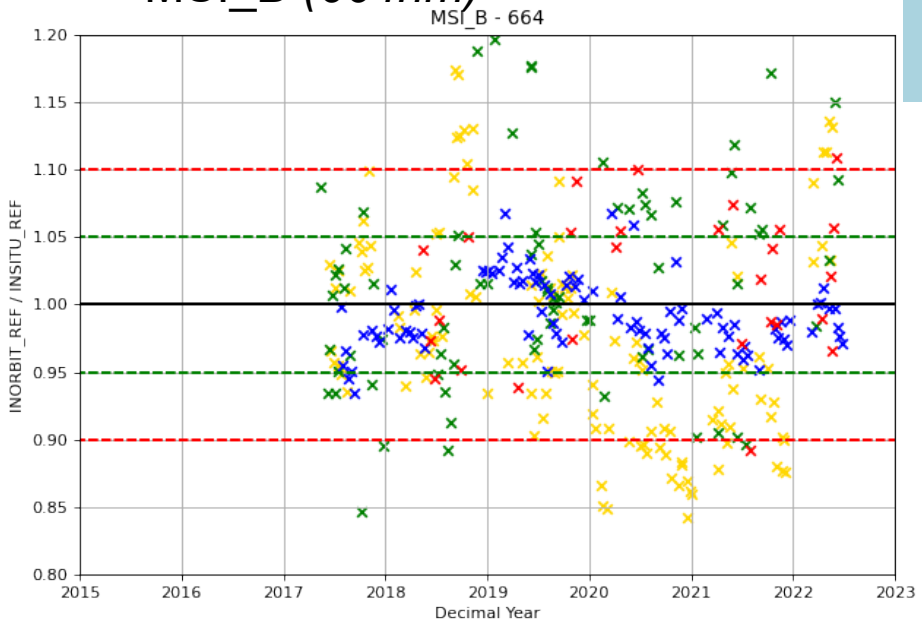
CEOS Committee on Earth Observation Satellites

RVUS LCFR
GONA BSCN

MSI_A *(664nm)*



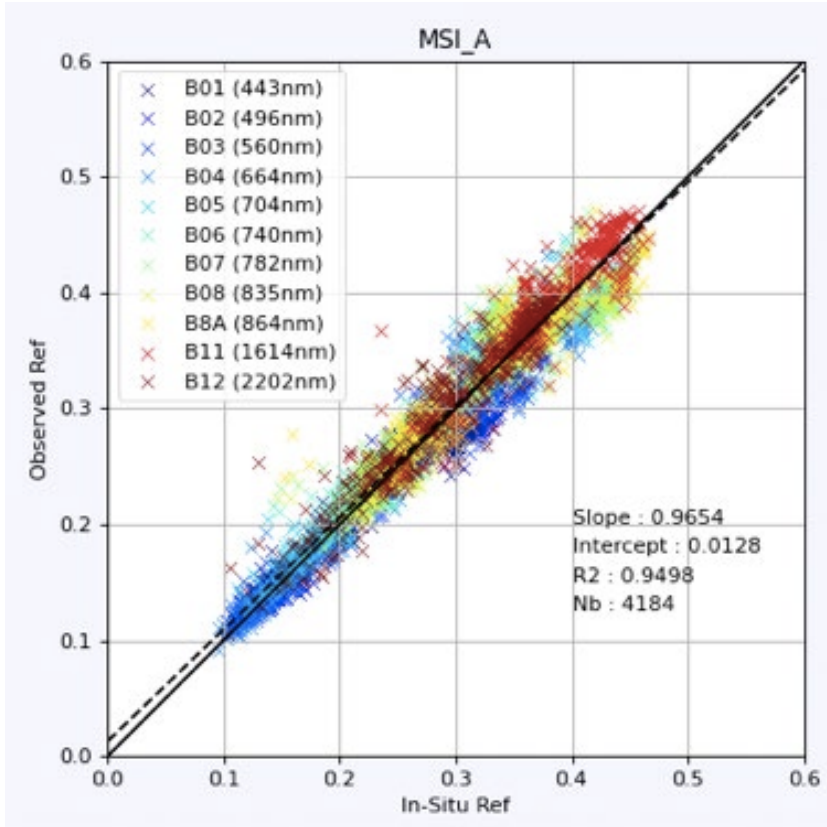
MSI_B *(664nm)*

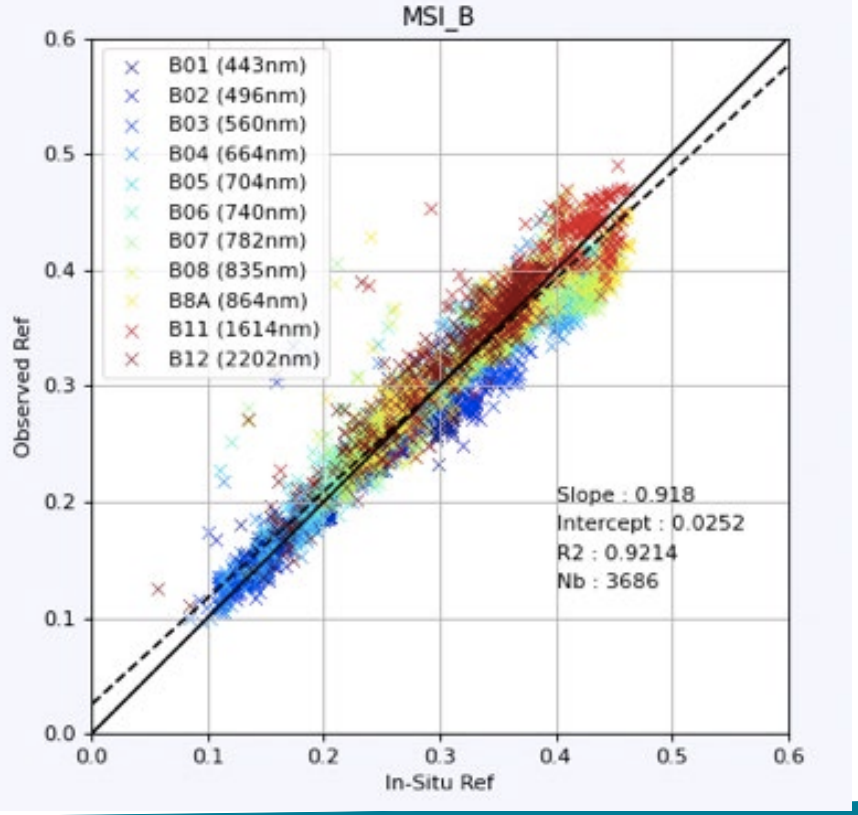


Absolute Radiometry Vicarious Validation

In-Situ measurements: over RadCalNet dataset up to May. 2022: (TOA reflectance, NADIR-view)

- **About 400** overpasses **S2A** and **350** overpasses **S2B**
- ROI: 0.1°x0.1° latitude x Longitude



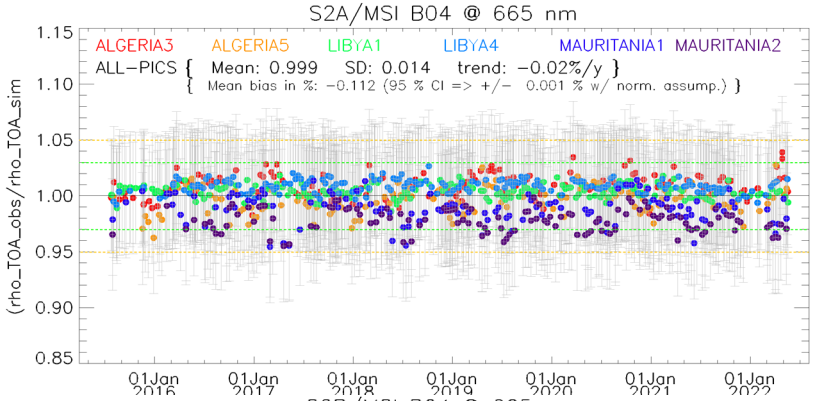


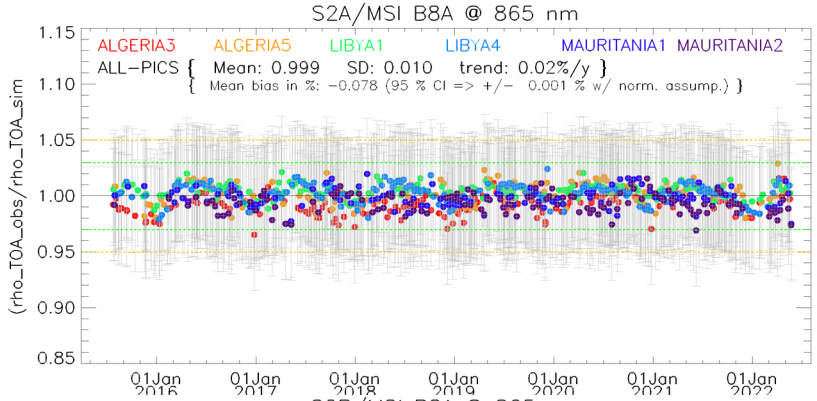
Multi-temporal Relative Radiometry Vicarious Validation

Desert-PICS Method : 6 CalVal sites & time-series up to May 2022

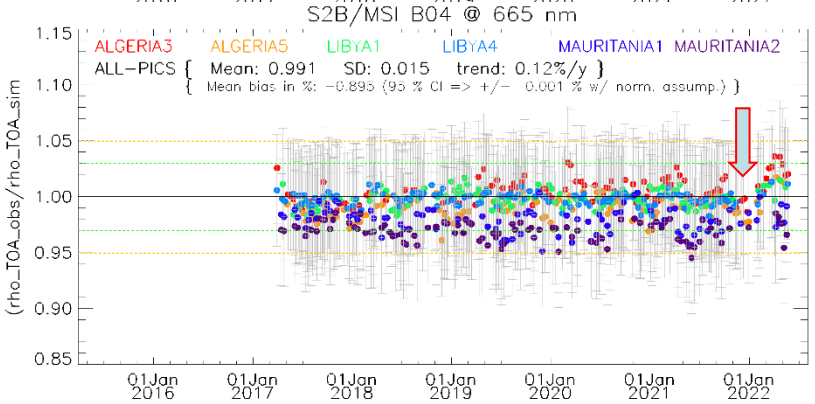
- **S2A/MSI**; 882 acquisitions used; VNIR are within 3% ; No detectable trend
- **S2B/MSI**; 664 acquisitions used; VNIR are within 3% ; No detectable trend

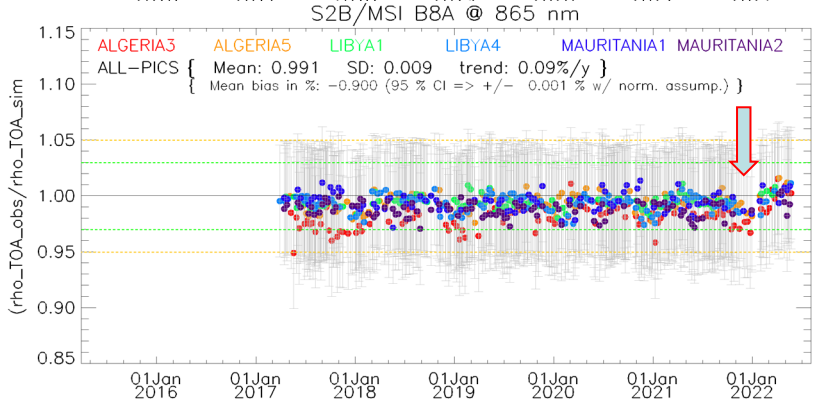
S2A/MSI





S2B/MSI



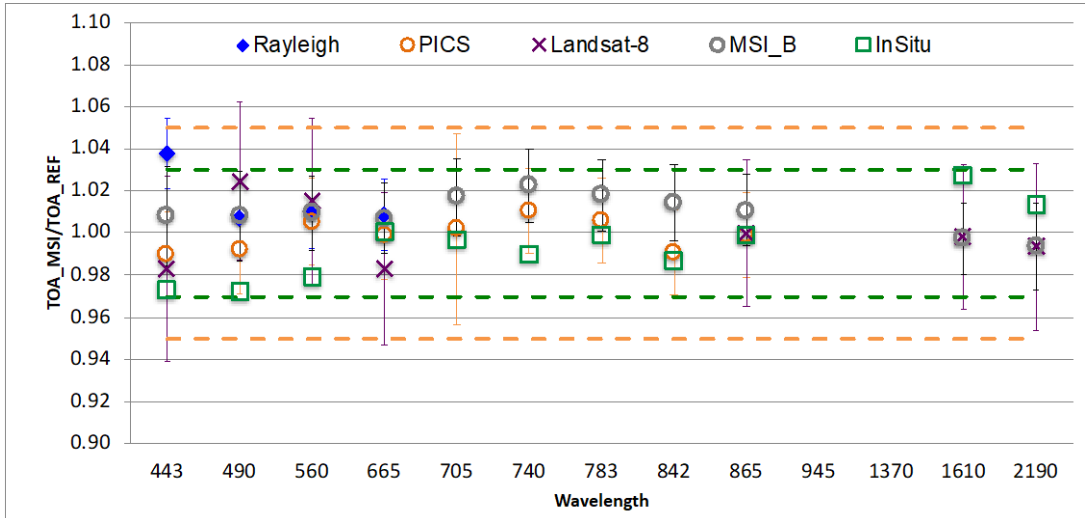


Wavelength (nm)	MSI-A	MSI-B
443	0.989	0.978
490	0.991	0.986
560	1.005	1.003
665	0.999	0.991
705	NA	NA
740	1.011	1.007
784	1.006	0.989
842	0.991	0.983
865	0.999	0.991

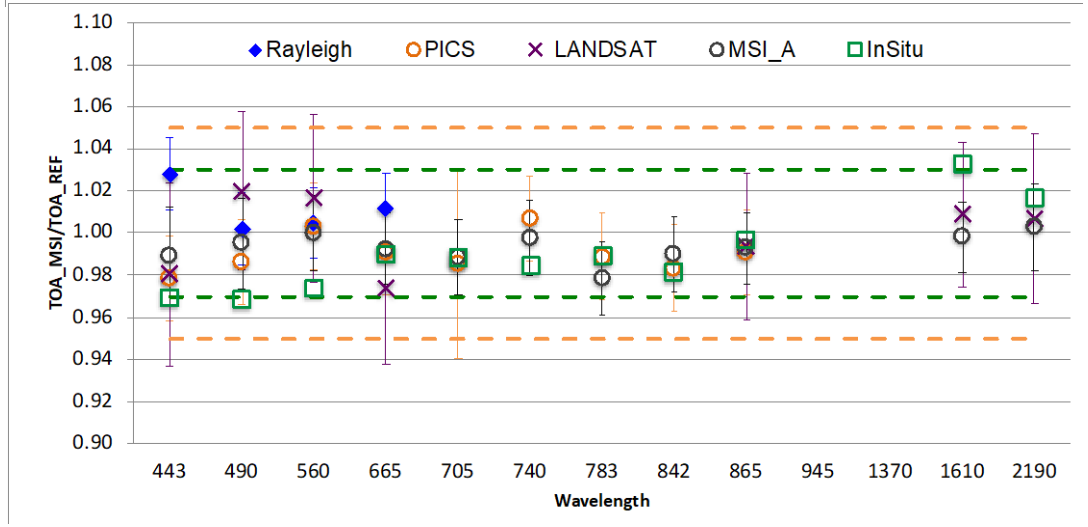
Synthesis over the Radiometry Vicarious Validation

- Good consistency over all the methods
- Results are within 3% (mission target req.)
- Maximum discrepancy is observed over
  - Rayleigh B01
  - Matchups with LS-8 B01 & B02
  - Matchups with In Situ B01, B02 & B11
- Good temporal stability (No trend detectable)
- Slight bias of MSI-A vs MSI-B of ~1% (Corrected since 25th Jan-2022)

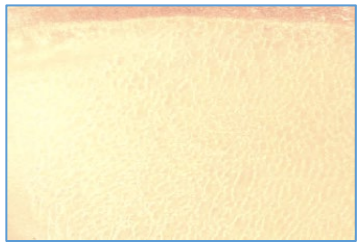
S2A

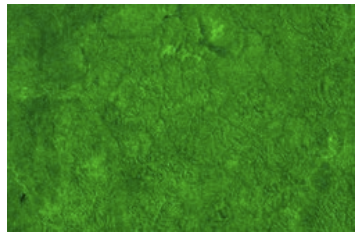
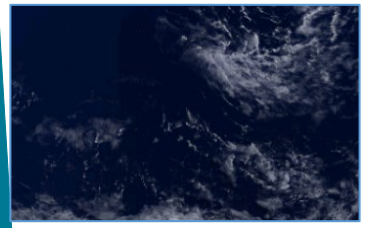


S2B



Sentinel-2A-2B radiometry intercalibration: Bias assessment

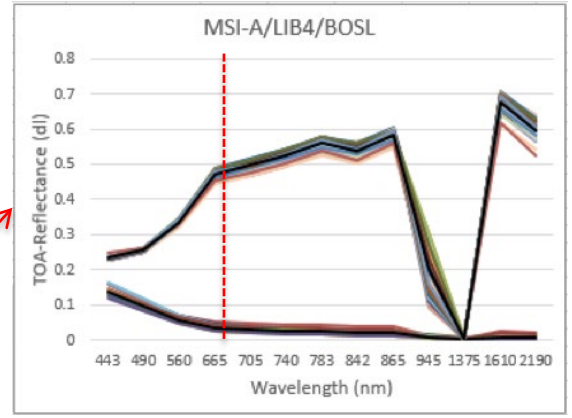


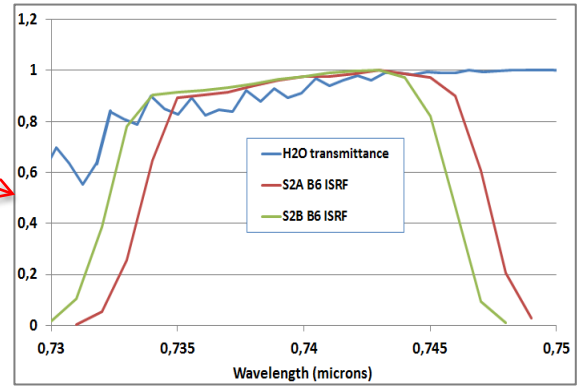



Cross-calibration – Up to 2021/05: Results

~1500 L1C Products 9 Desert/Ice-PICS	1220 L1C Products 6 Desert-PICS	165 L1C Products 6 Ocean-PICS

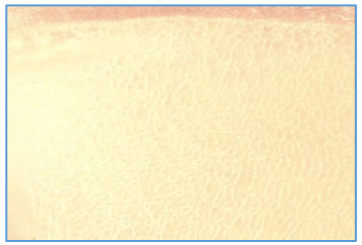
Band number	Wavelength (nm)	Bright sites		Dark sites	
		Angular-Matchups method	Deserts-PICS Method	Angular-Matchups method	Rayleigh-Scattering method
B01	443	1.014	1.013	1.005	1.013
B02	490	1.010	1.006	1.013	1.008
B03	560	1.009	1.003	1.018	1.007
B04	665	1.009	1.009	1.030	0.997
B05	705	1.017	1.014		
B06	740	1.021	1.005		
B07	783	1.017	1.018		
B08	842	1.011	1.008		
B8A	865	1.012	1.009		
Average		1.013	1.009	1.016	1.006
Average B01-B8A, excluding B06		1.012	1.010	-	-
Average B01-B03		1.011	1.007	1.012	1.009



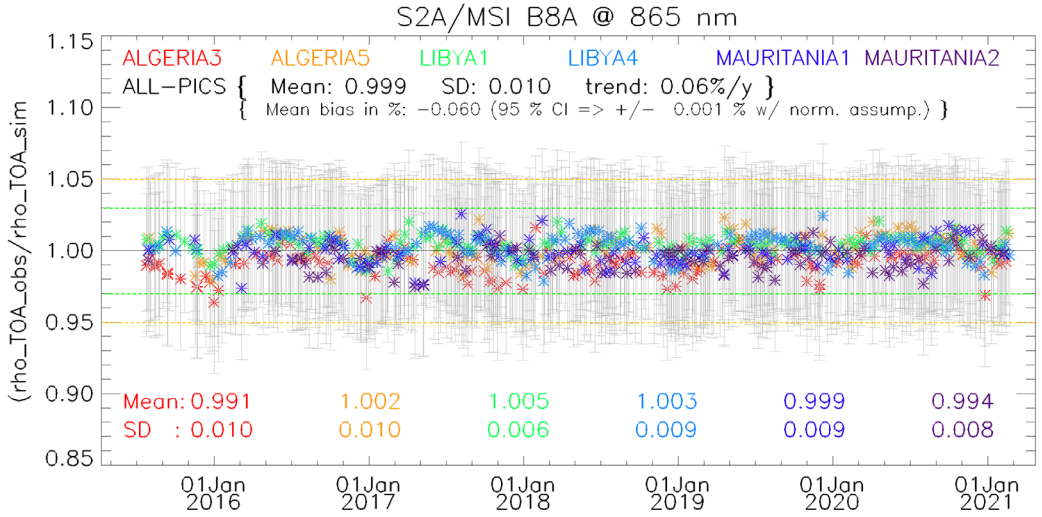


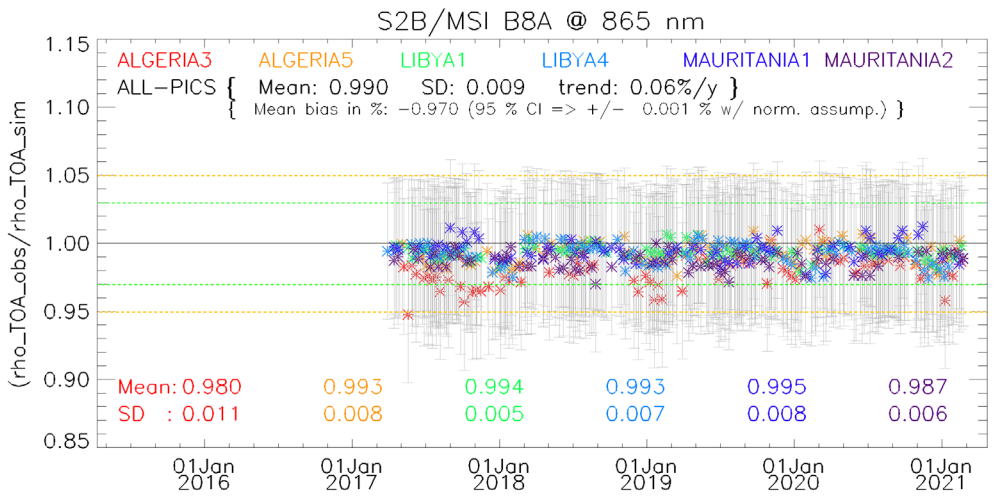
Sentinel-2A-2B radiometry intercalibration: Bias temporal variability

Desert-PICS method – Up to 2021/05 : Results



~1220 L1-C Products
6 Desert-PICS

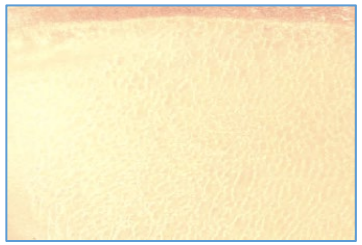


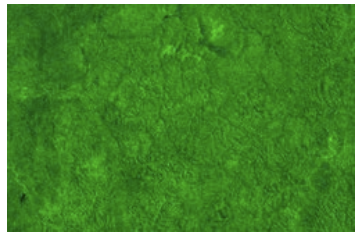


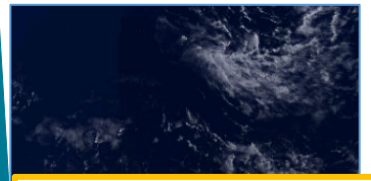
Trend for S2A/S2B:

- VNIR ~ 0.01- 0.2%

Sentinel-2A-2B radiometry intercalibration: Bias temporal variability



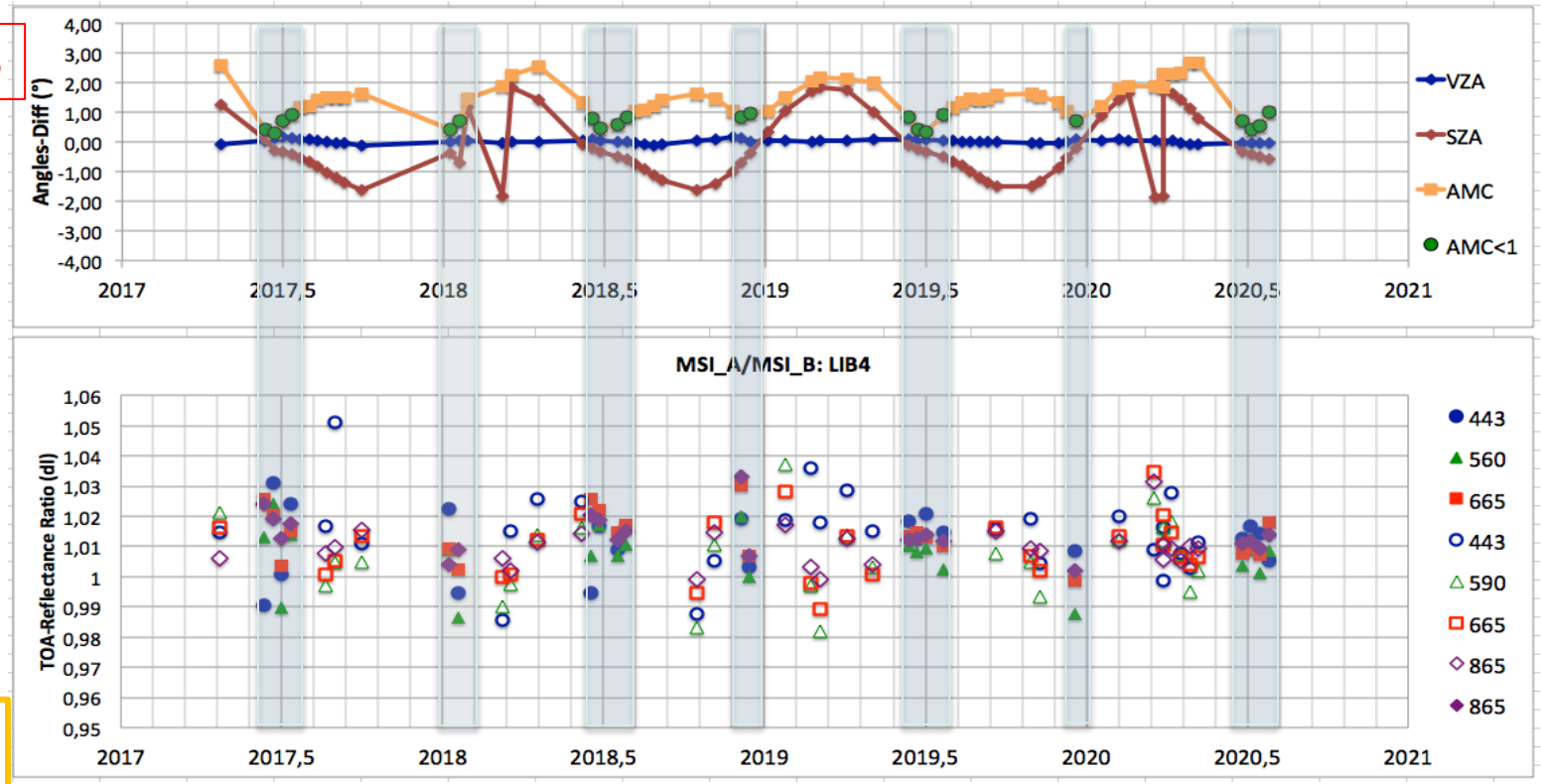




Angular matchups for sensor-to-sensor inter-calibration method: Results

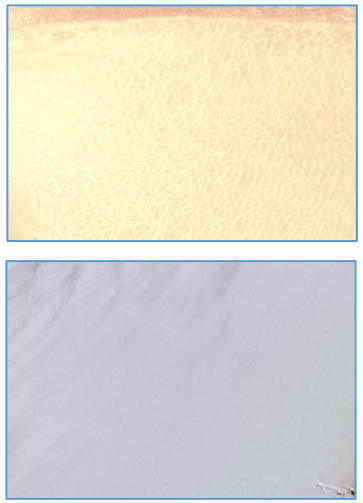
~1500 L1-C Products
9 Desert/Ice-PICS

LIBYA4; REF: MSI-B



$$AMC = \sqrt{([SZA_1 - SZA_2]^2 + [VZA_1 - VZA_2]^2 + \frac{1}{4}[|RAA_1| - |RAA_2|]^2)}$$

Sentinel-2A-2B radiometry intercalibration: Bias temporal variability



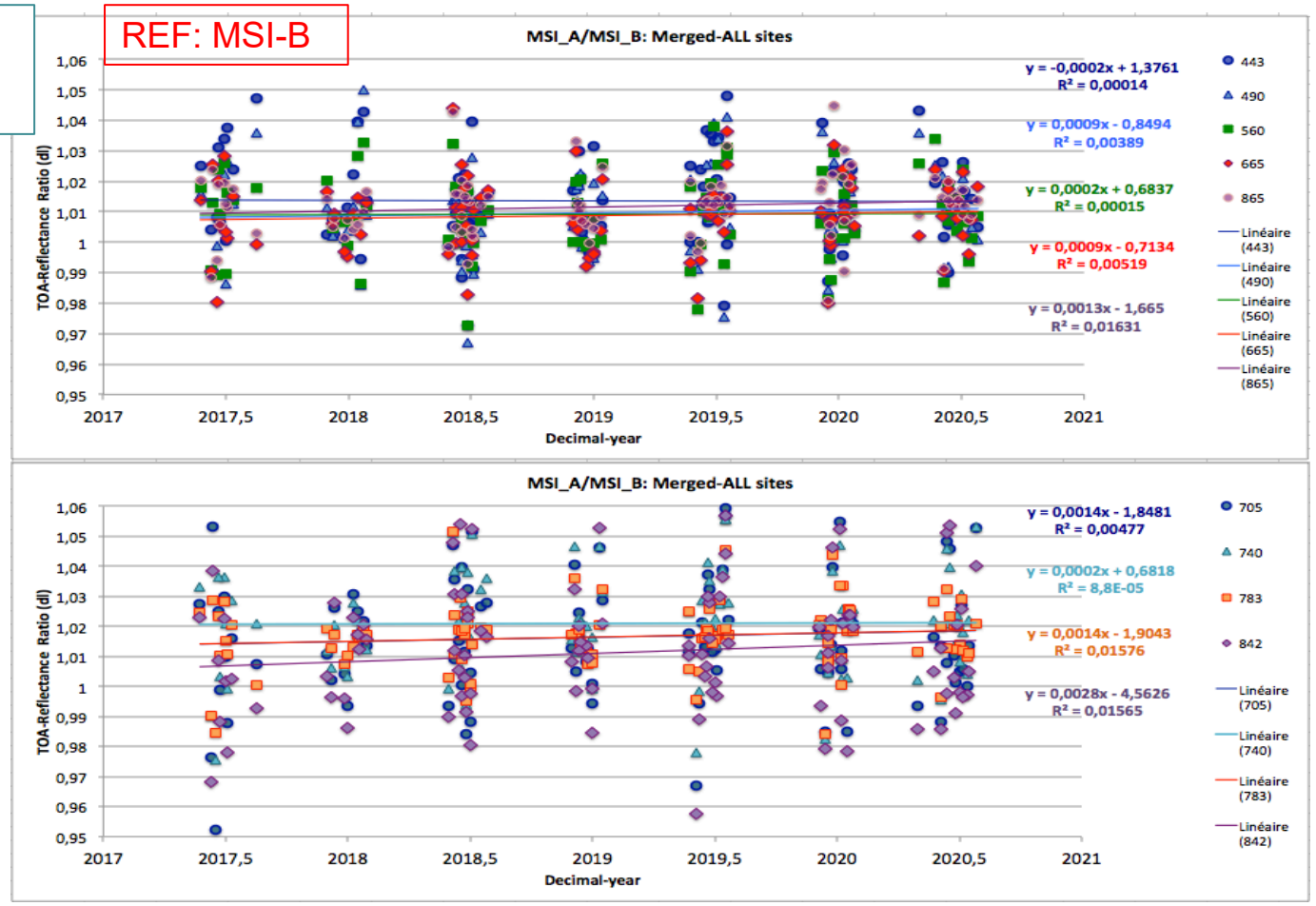
Angular matchups for sensor-to-sensor inter-calibration method: Results

~500/1500 L1-C Products
9 Desert/Snow-PICS

Algeria3,
Algeria5,
Libya1,
Libya4,
Mauritania1,
Mauritania2,
Dome-C,
Gobabeb,
RRVP

Trend for S2A/S2B:

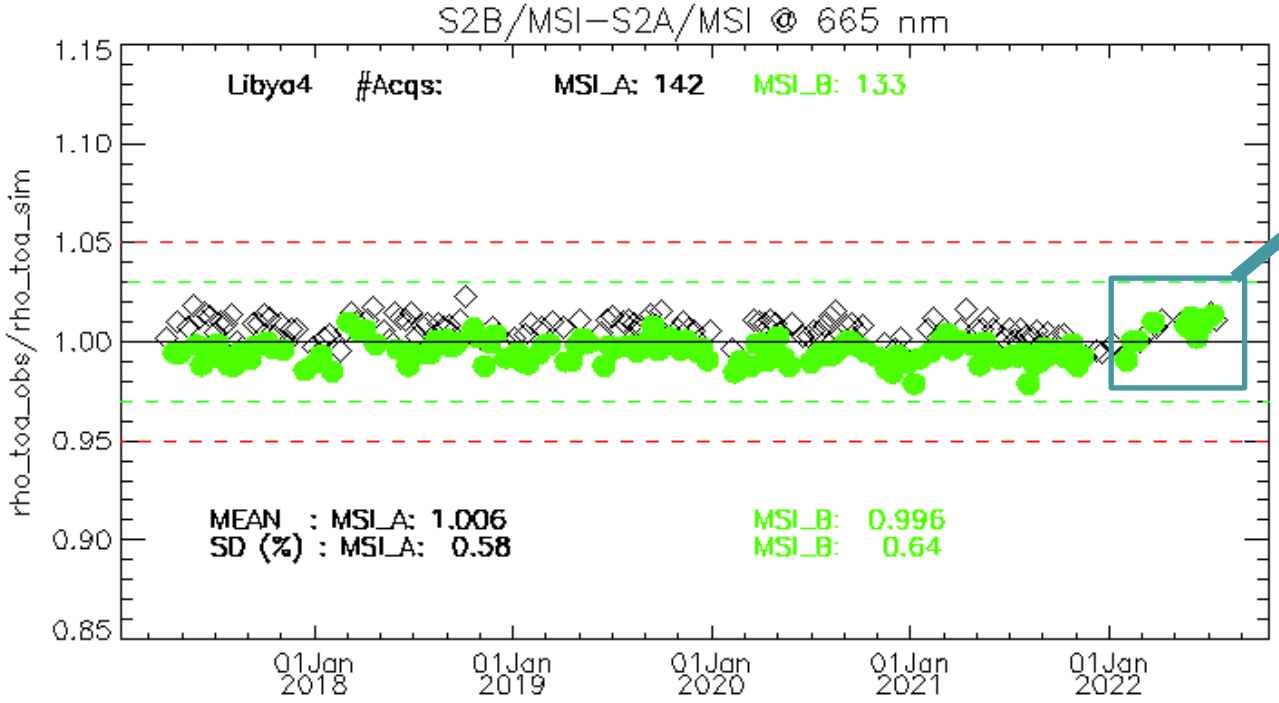
- VNIR ~ 0.01- 0.1%

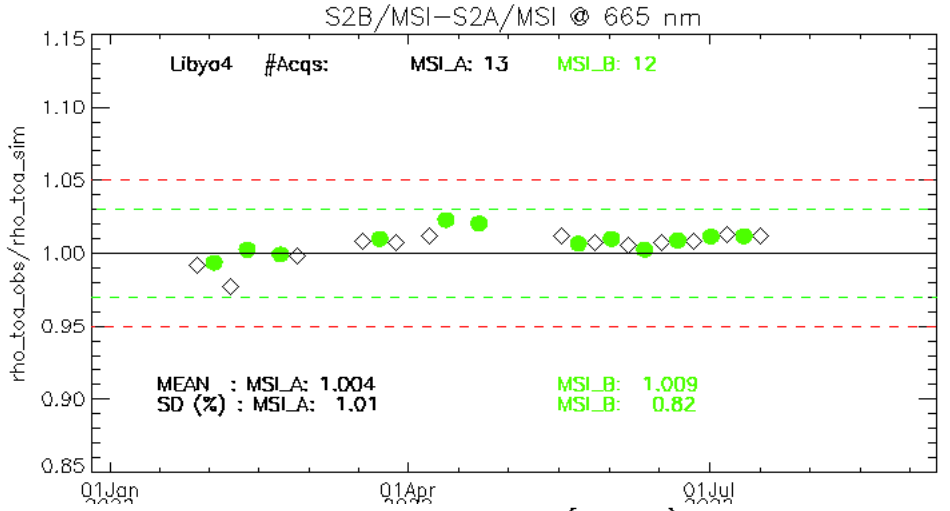


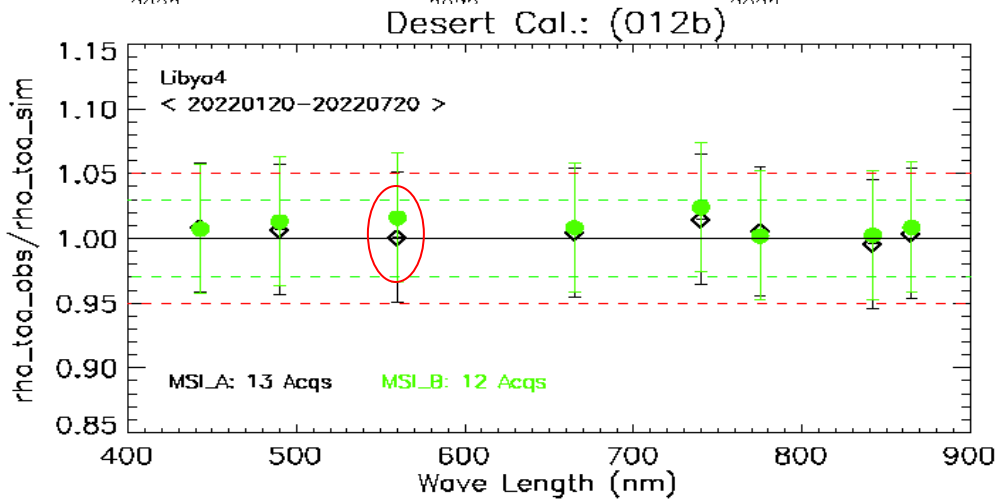
Sentinel-2A/B and LANDSAT-8/9 Radiometry intercomparison

Desert-PICS Method : X-mission intercomparison (LIBYA4): MSI-A/MSI-B

July 2022



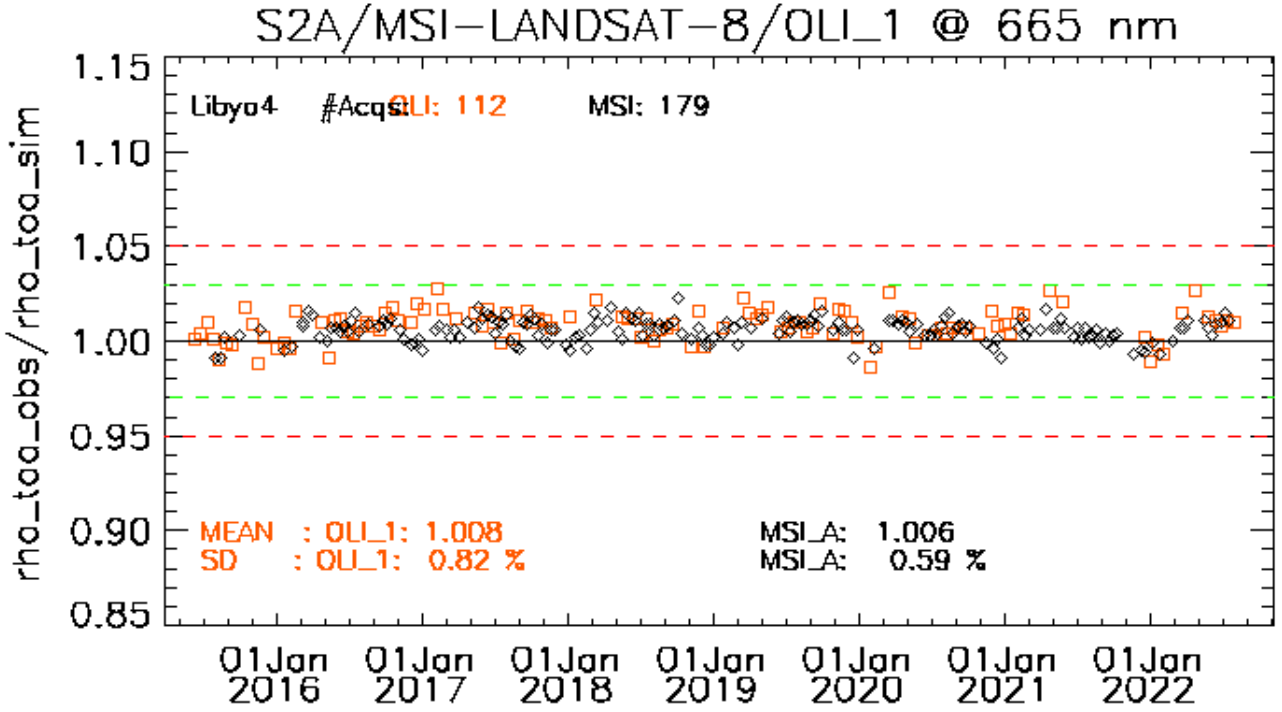


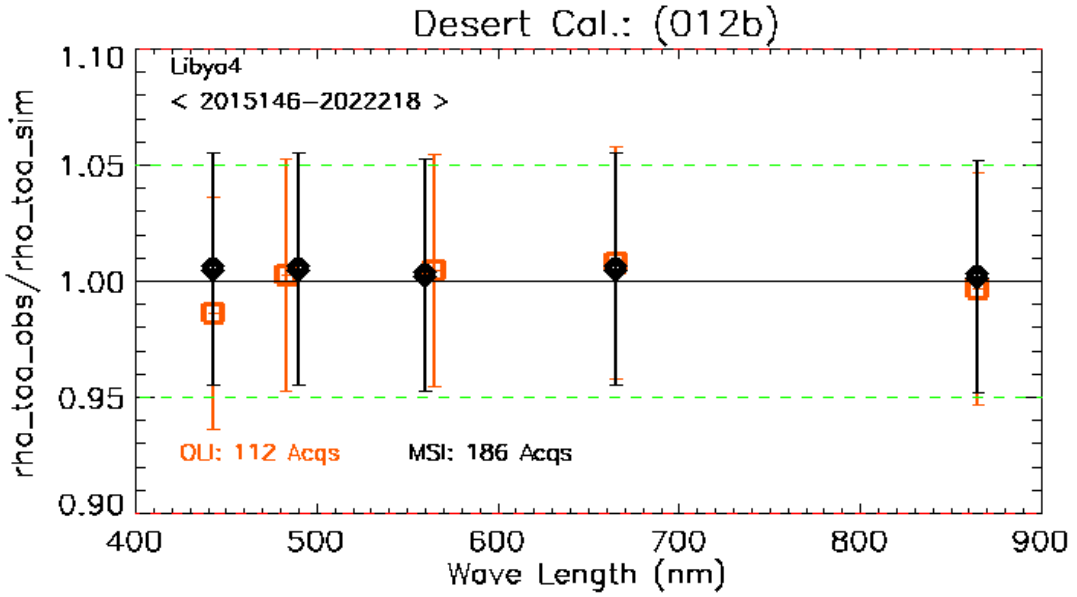


Sentinel-2A/B and LANDSAT-8/9 Radiometry intercomparison

Desert-PICS Method : X-mission intercomparison (LIBYA4)

MSI-A/OLI-1

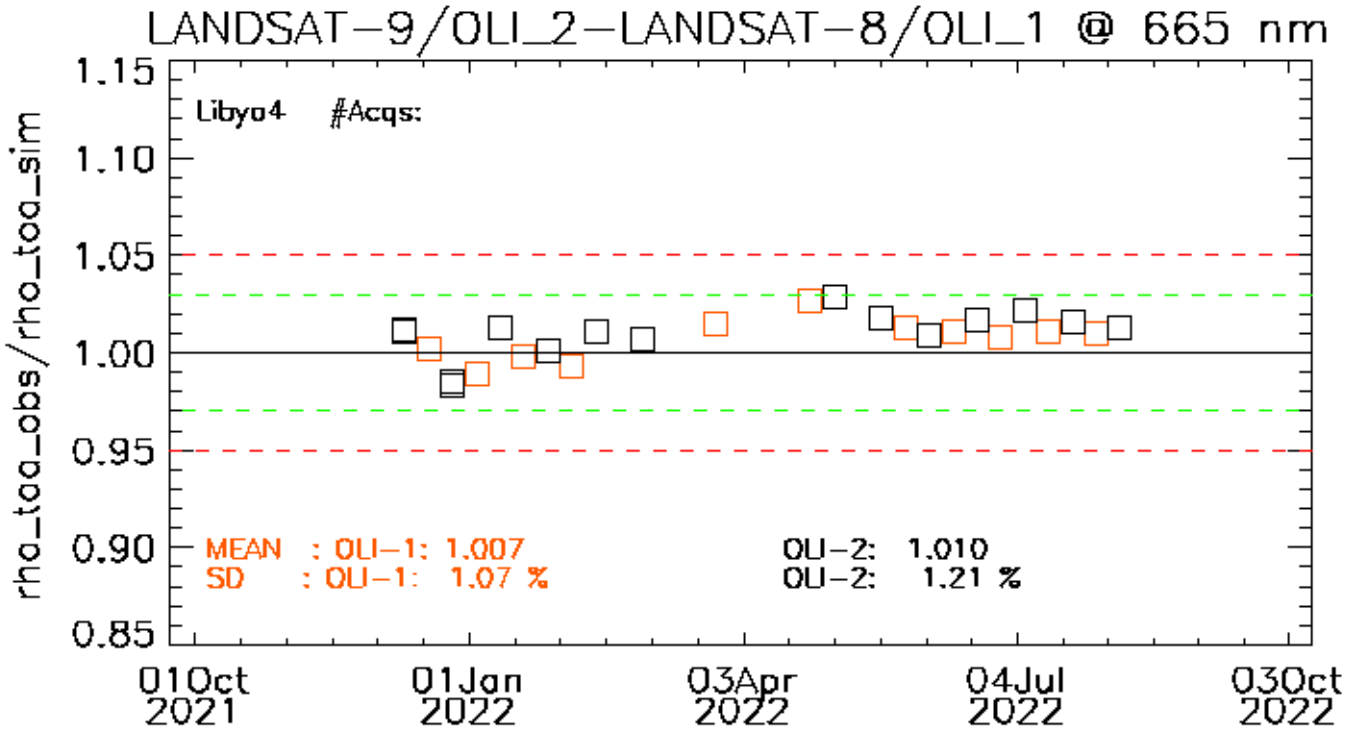


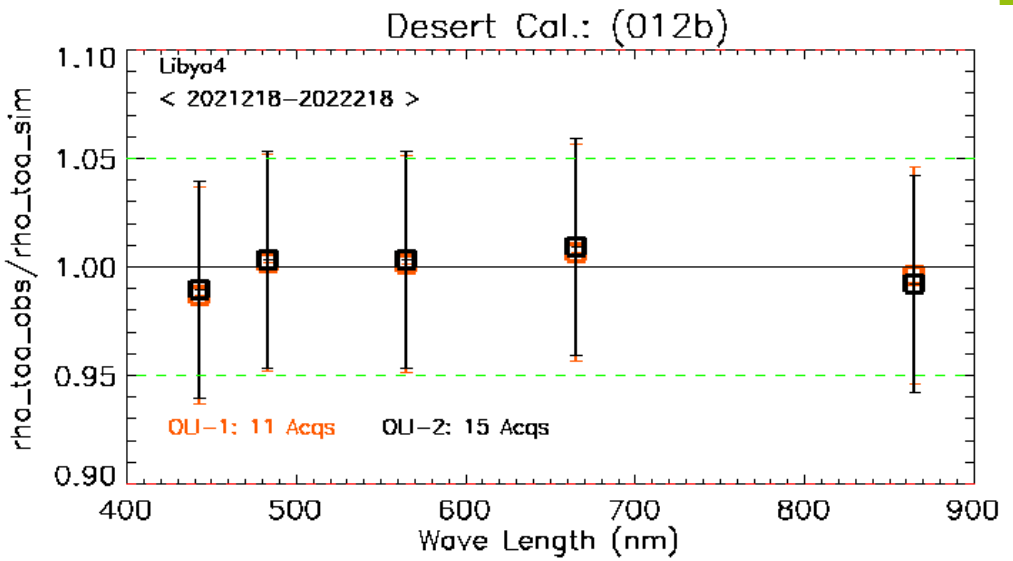


Sentinel-2A/B and LANDSAT-8/9 Radiometry intercomparison

Desert-PICS Method : X-mission intercomparison (LIBYA4)

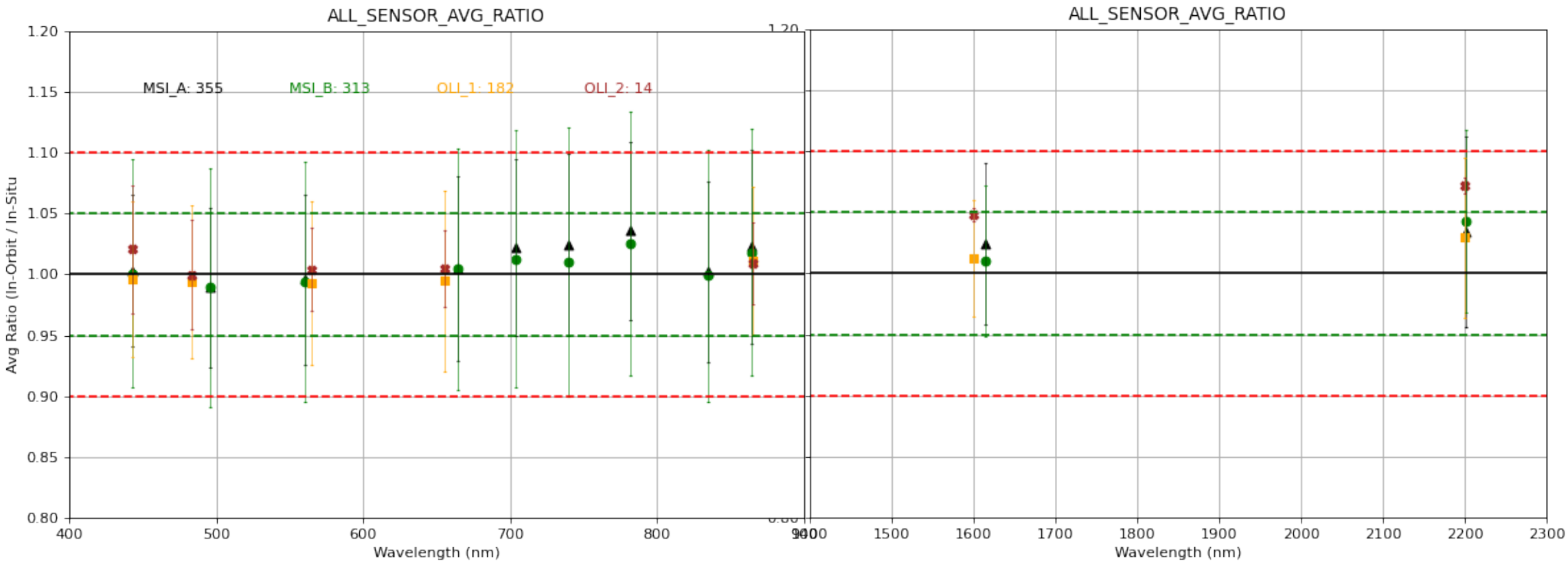
OLI-2/OLI-1





Sentinel-2A/B and LANDSAT-8/9 Radiometry intercomparison

In-Situ measurements: X-mission intercomparison over RadCalNet test sites



Conclusions

- Good consistency over the results of the different methods: Angular-Matchups, Rayleigh scattering (over VIS bands), and PICS (over VNIR bands)
- S2A/MSI shows brighter TOA-reflectance than S2B/MSI over VNIR bands by 1-2%, with an average value of 1.1%
- Successful intercalibration and correction of the bias S2A/S2B
- No significant temporal variability over PICS Cal/Val sites for the VNIR bands.
- Good consistency with similar missions (<2%)
- RadCalNet good quality dataset and very useful for CalVal activities

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Sentinel-2A /2B fly at 180° apart.
(Credit: www.esa.int)