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OPT-MPC Copernicus Sentinel Optical Mission Performance Cluster

Copernicus Sentinel-2 Level-1 Radiometric Validation status from the Optical-Mission Performance Cluster: Operational and Collection-1 Radiometry Verification

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Agenda

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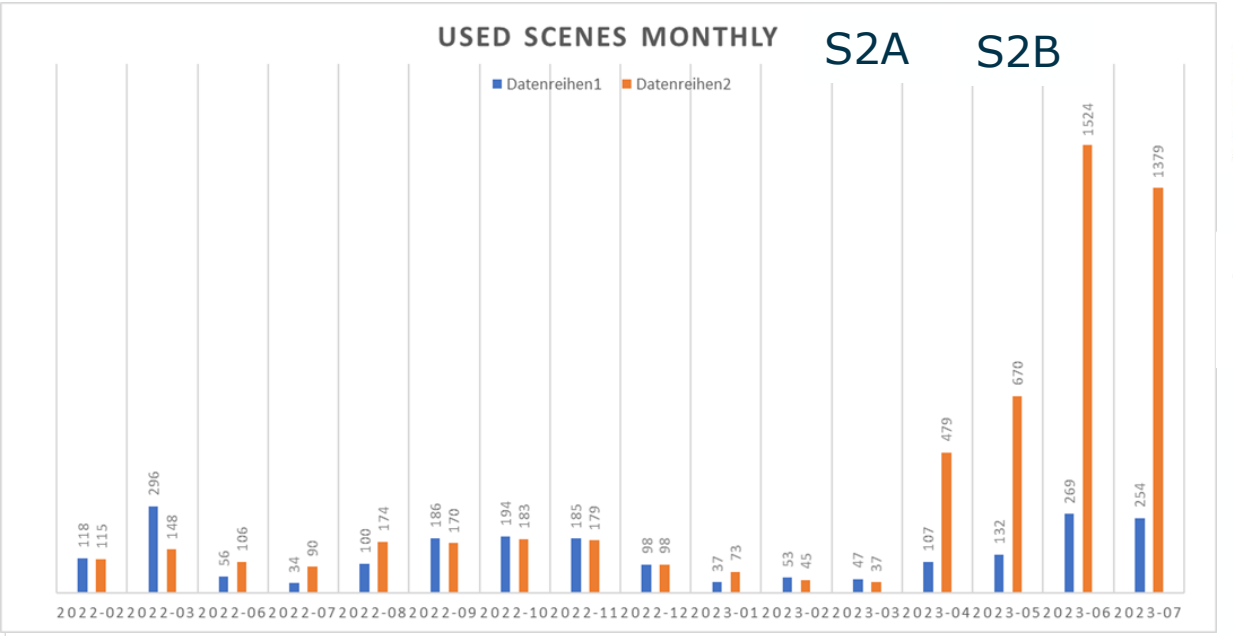
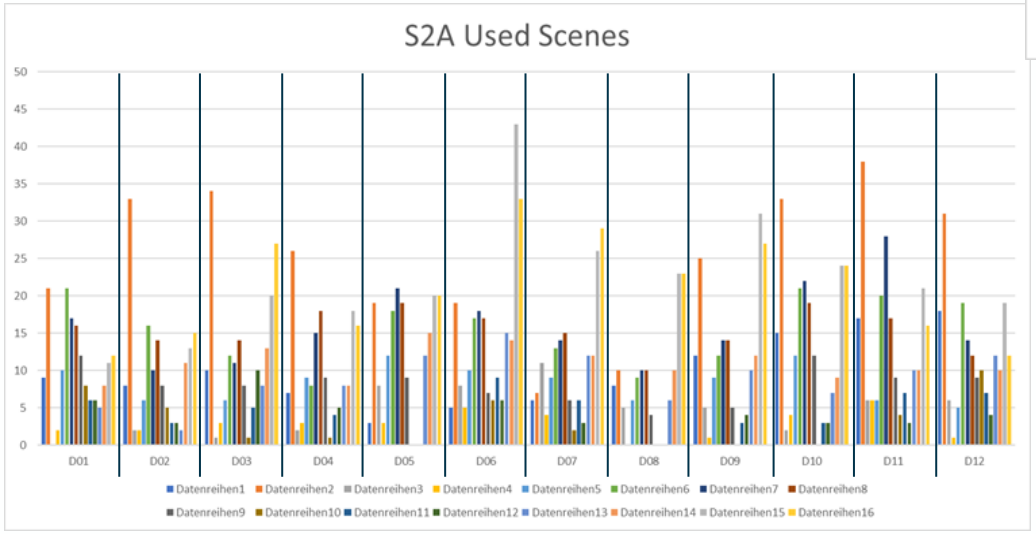
Copernicus Sentinel
Optical Mission Performance Cluster

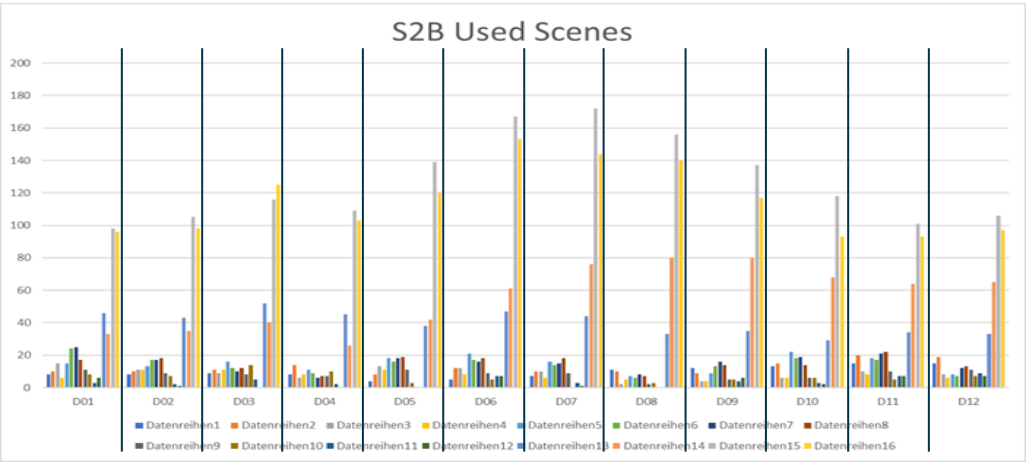
- FPN and SNR validation results
- Radiometry vicarious validation
- Radiometry X-mission inter-comparison
- Collection-1 Radiometry Verification
- MTF measurements
- Conclusions

FPN and SNR validation activities

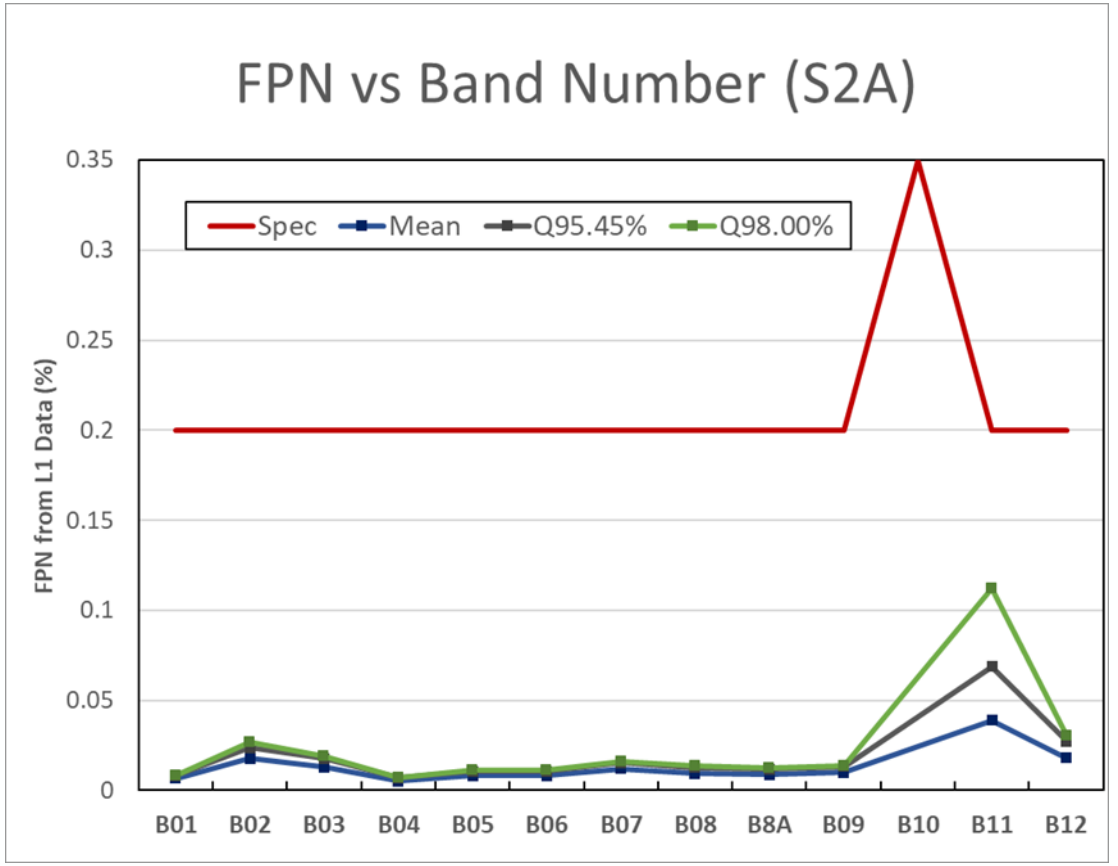
- Fewer scenes acquired in 2023
- Requested additional scenes from Algeria and Saudi Arabia
- Many more scenes giving better detector coverage
- More scenes in S2B than S2A

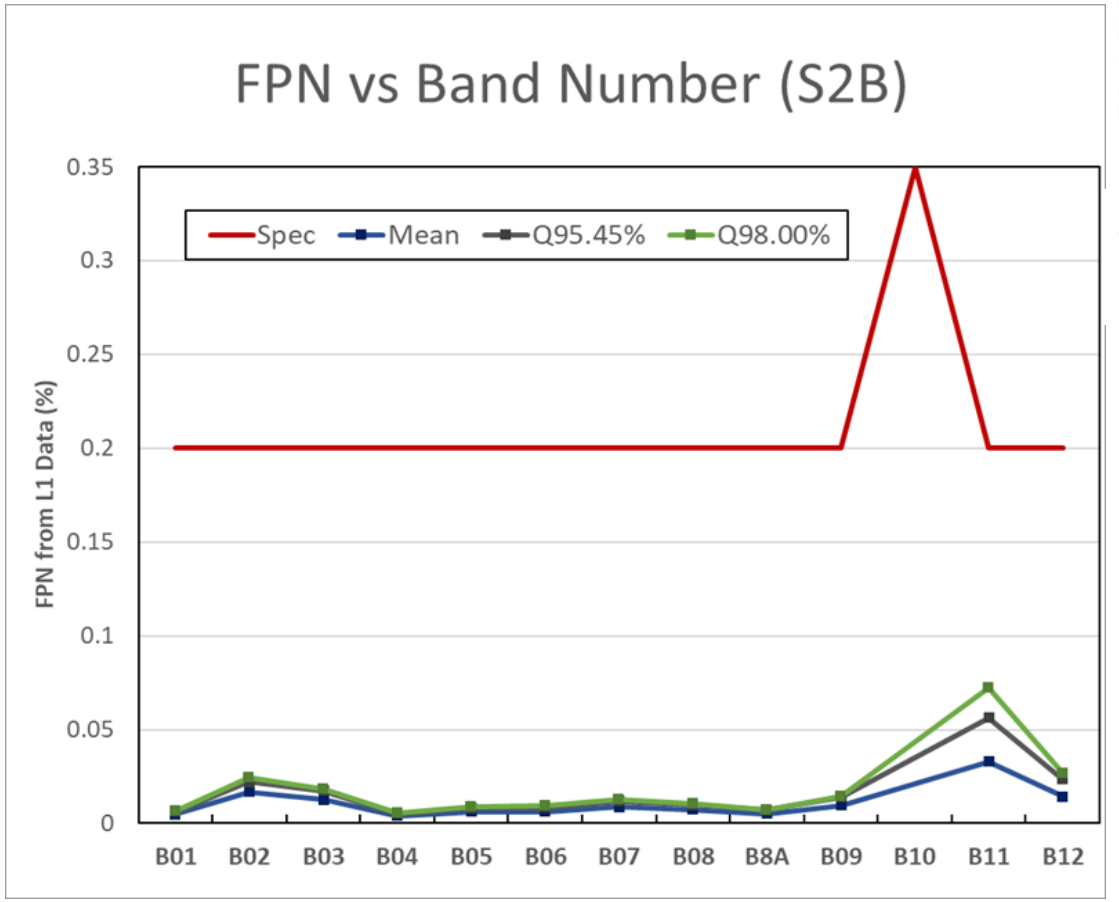






FPN and SNR validation activities

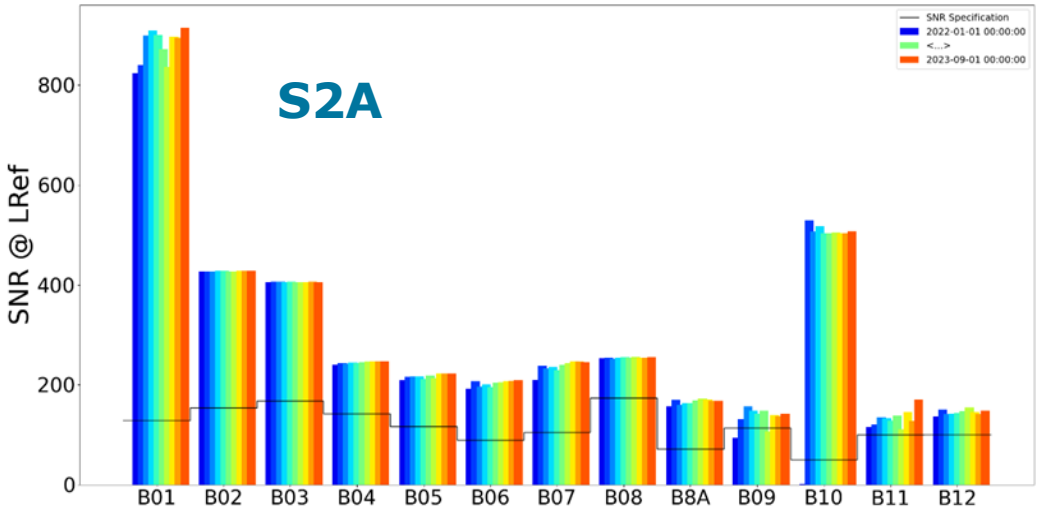


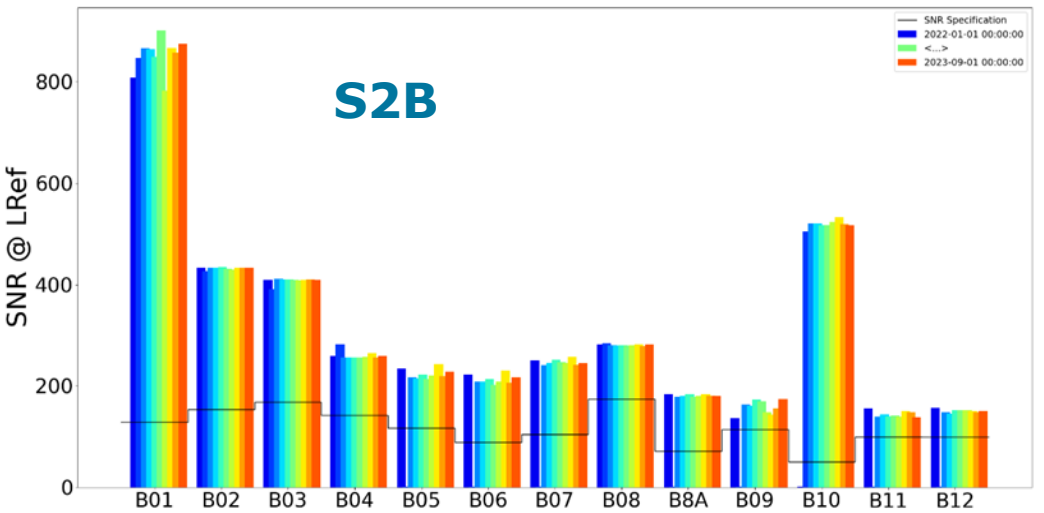


S2A

S2B

FPN and SNR validation activities





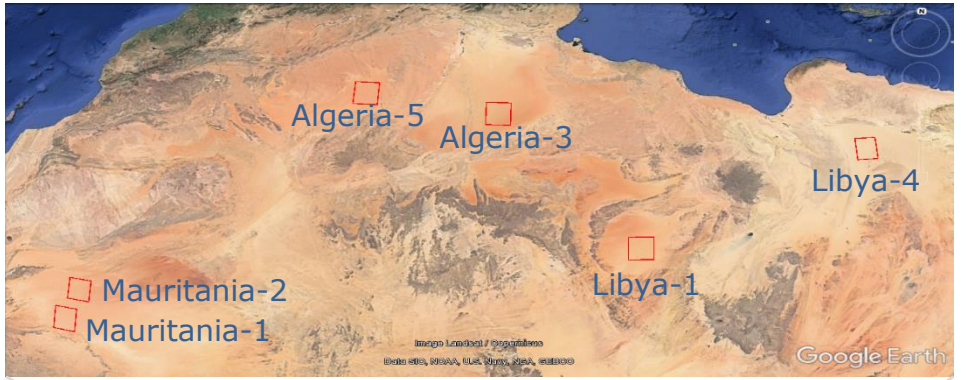
Calculated SNR exceeds specifications for all bands
Calculated SNR temporally stable (Feb 2022-April 2023)

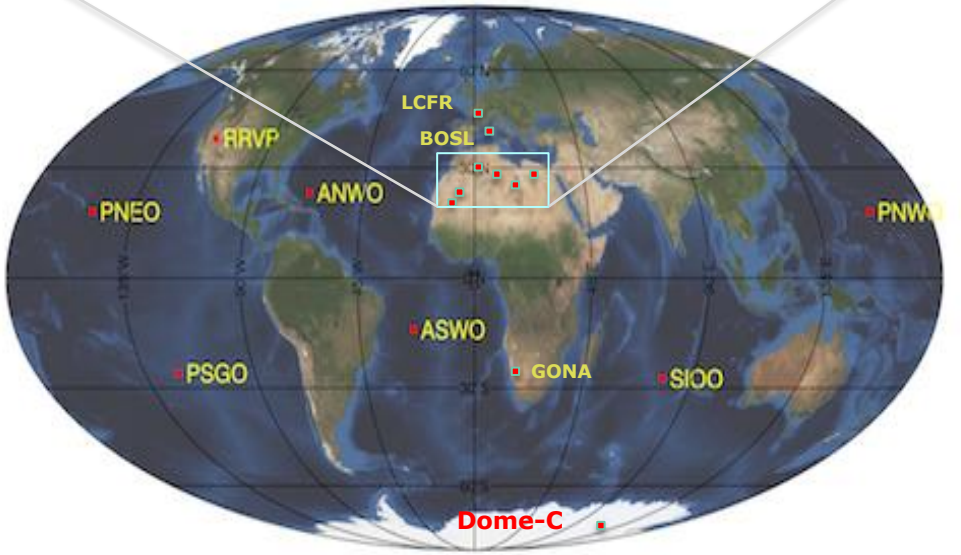
Radiometry vicarious validation activities

CalVal-sites Location

10 Land; 7 Water

Bright sites:	Dark sites:
Desert: ▪ 6 CEOS-PICS ▪ Gobabeb ▪ RRVP ▪ BSCN	Land: ▪ La Crau
Ice/Snow ▪ DOME-C	Water ▪ 6 Open Ocean ▪ Boussole (Costal)





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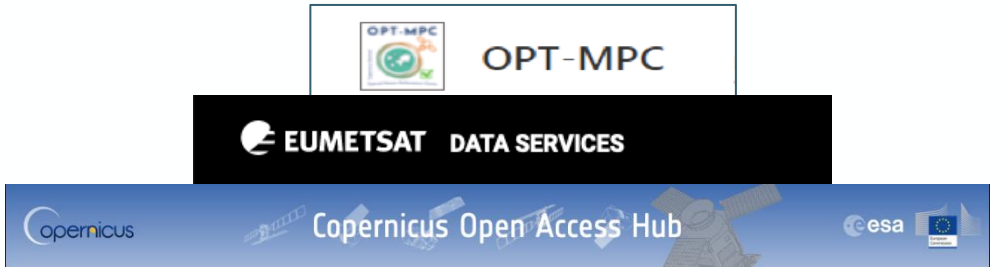
Radiometry vicarious validation activities

Data Sets

- L1C MSI-A & MSI-B: OPT-MPC-DAGC & https://scihub.copernicus.eu/
- L1TP LANDSAT-8 & 9: https://earthexplorer.usgs.gov/
- L1B OLCI-A & OLCI-B: OPT-MPC & https://scihub.copernicus.eu/
- RadCATs: are provided by the NASA Landsat Cal/Val Team as part of the ESA expert users effort / UoA
- RadCalNet: https://www.radcalnet.org/



Radiometry vicarious validation activities

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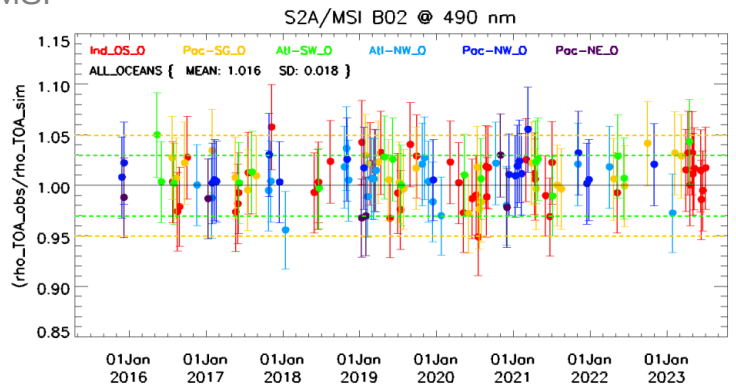
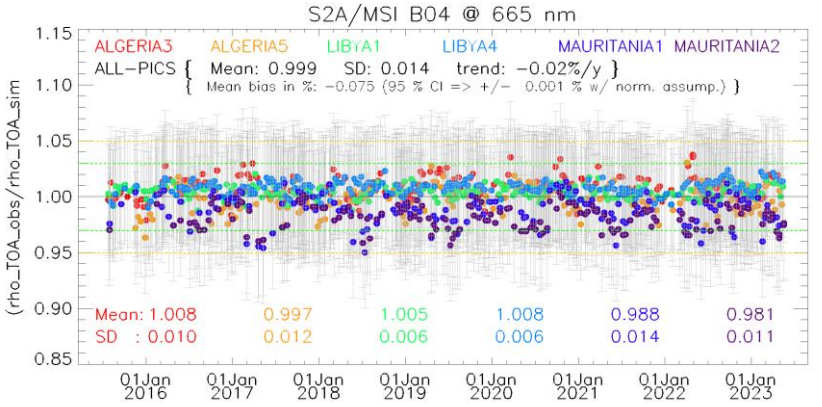
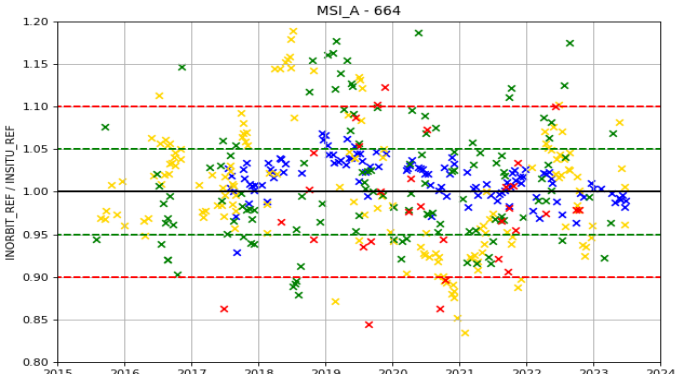
RAYLEIGH & **Desert-PICS Methods** 12 CalVal sites & time-series up to July 2023

In-Situ measurements: 4 CalVal RadCalNet sites & time-series up to June 2023.

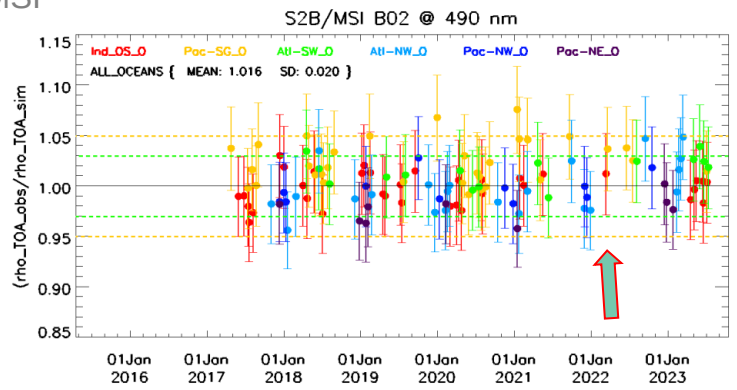
S2A/MSI

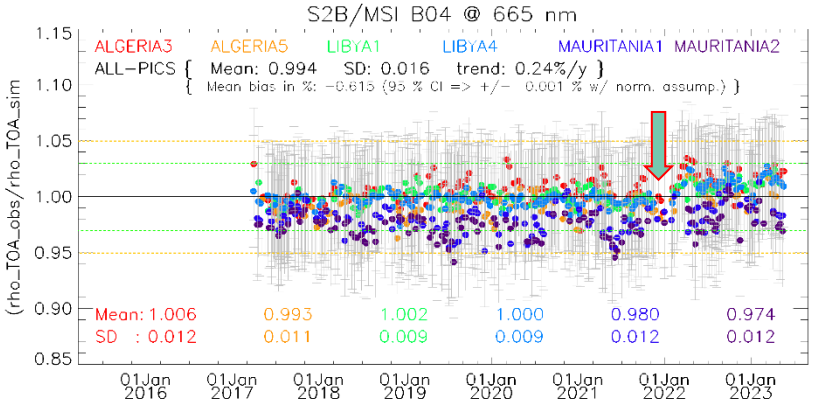


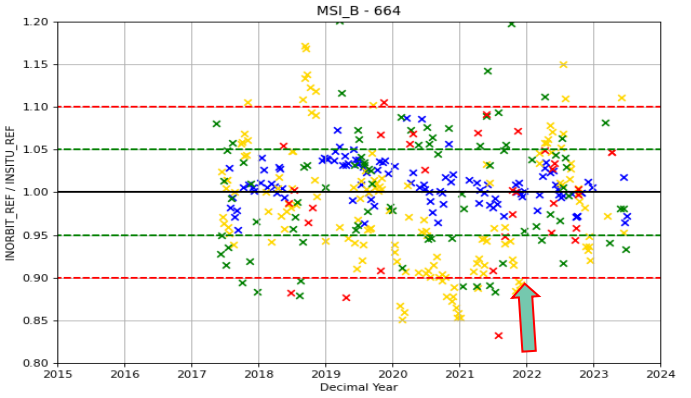




S2B/MSI







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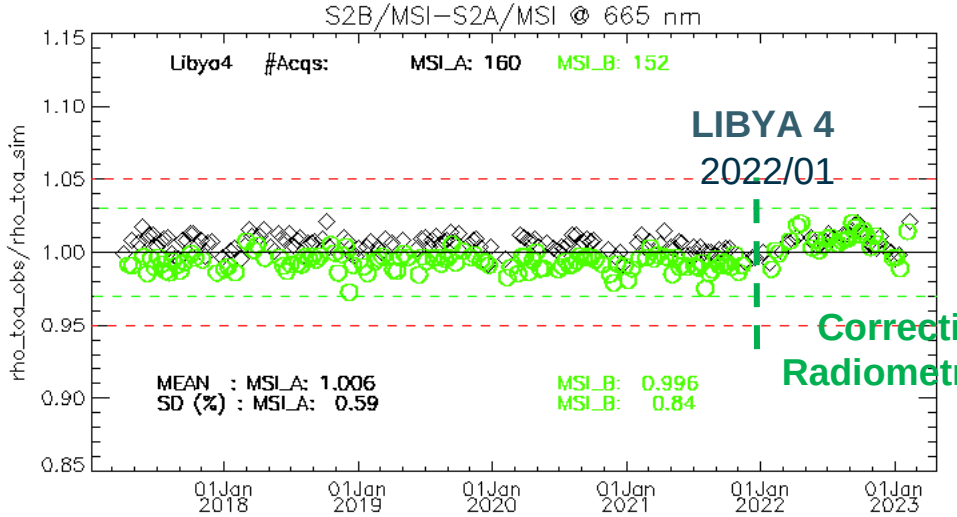
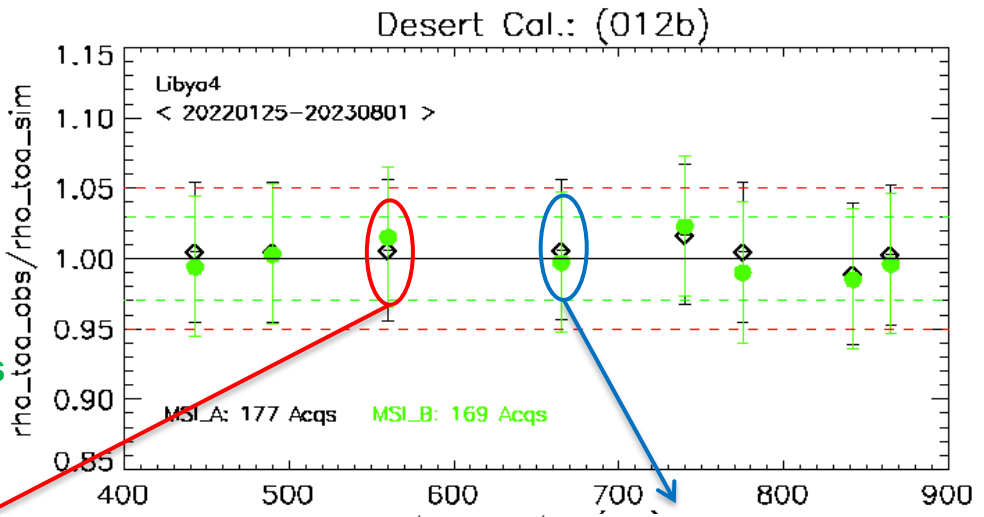
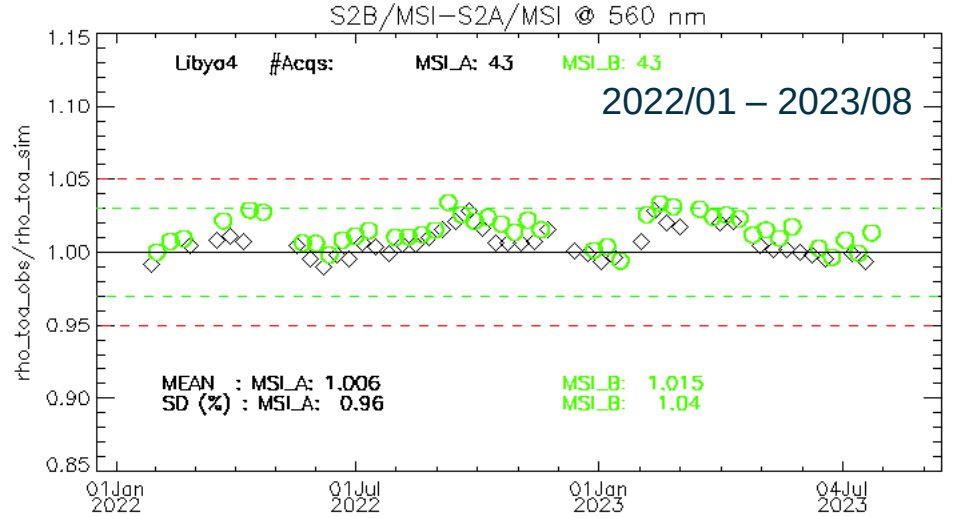
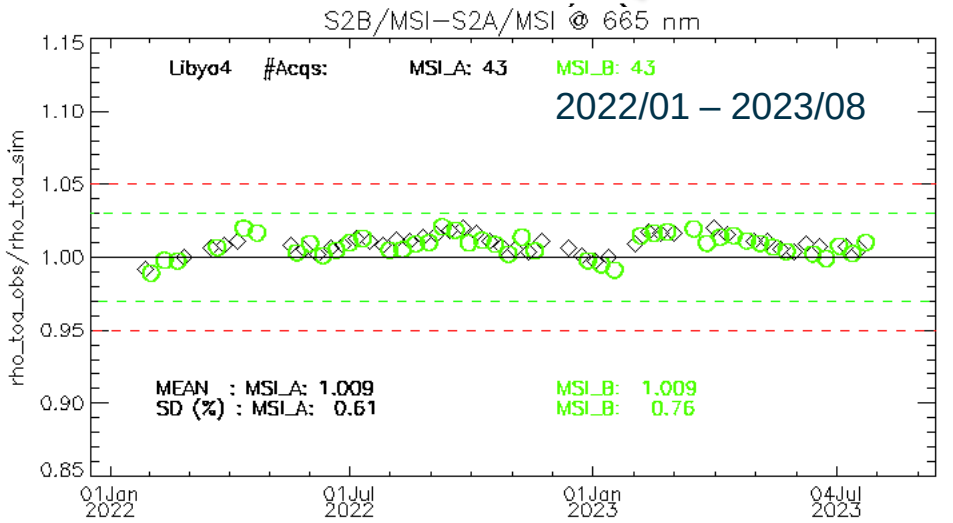
Radiometry Cross-mission Inter-comparison



Correction of Radiometric Bias

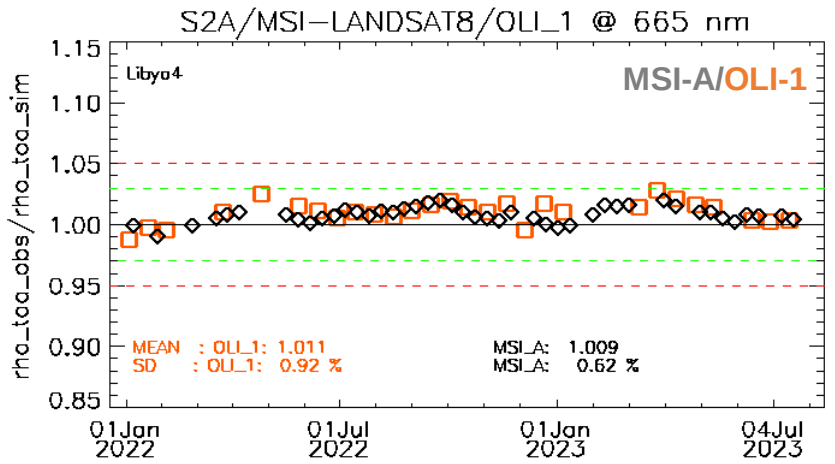


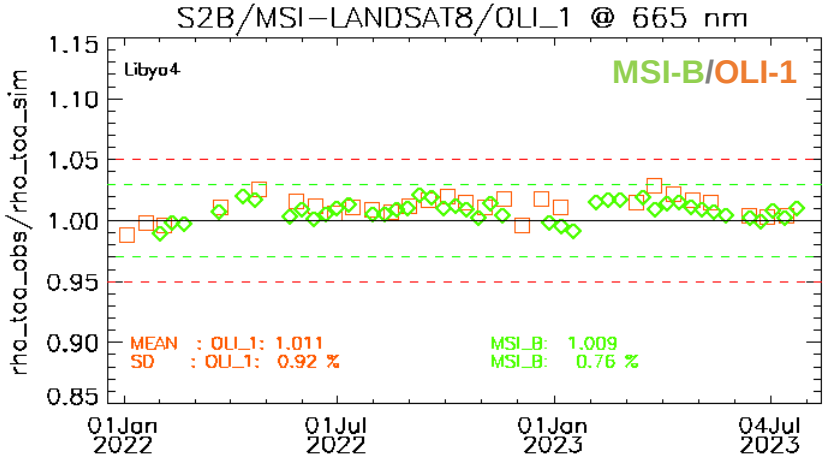


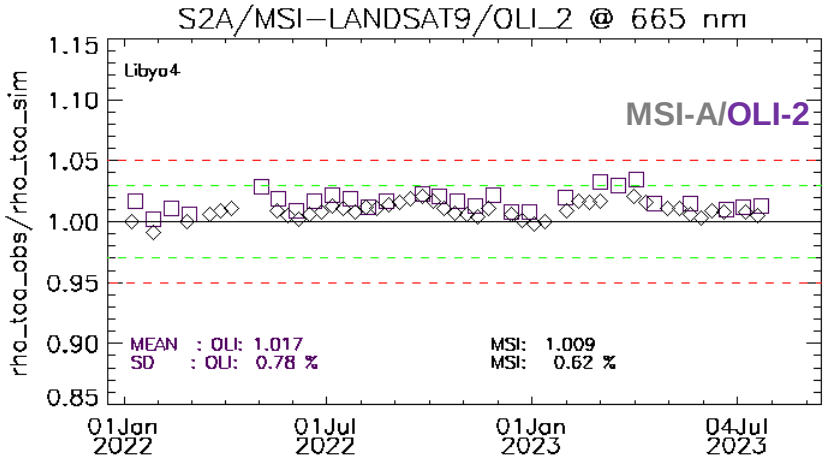


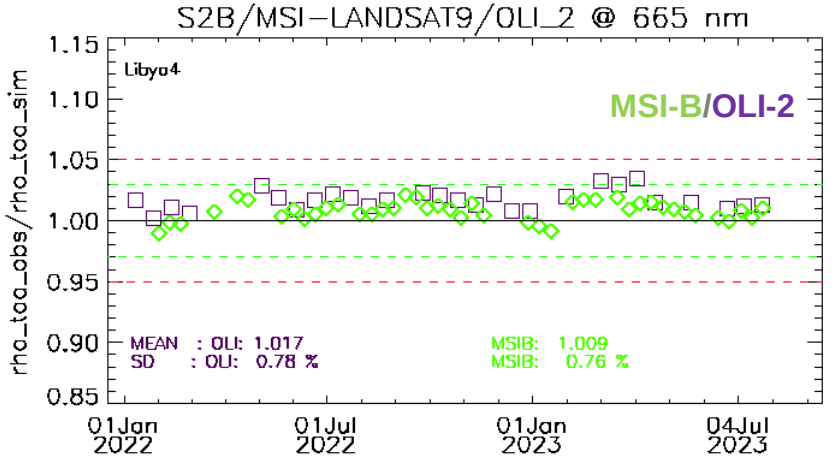
Radiometry Cross-mission Inter-comparison

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







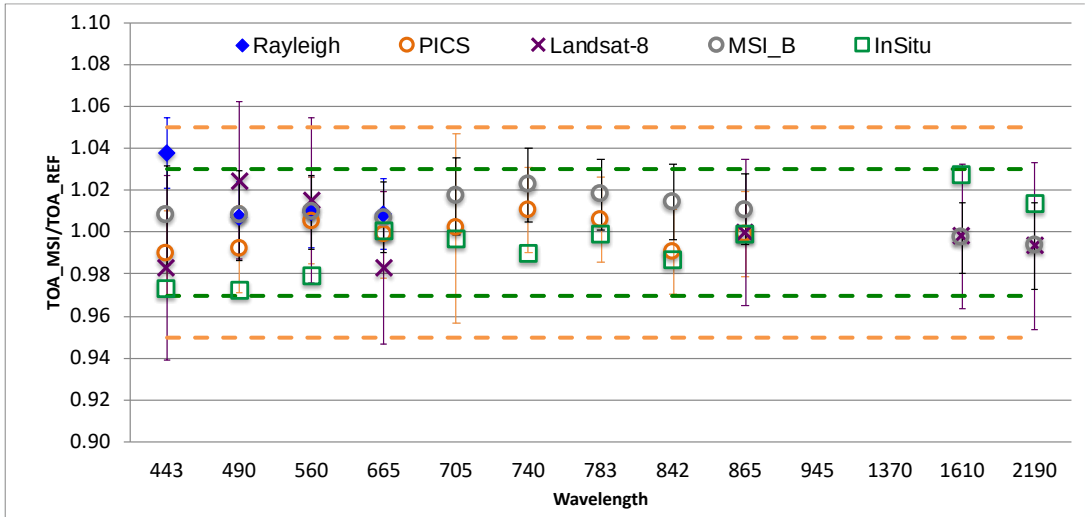


Radiometry vicarious validation activities

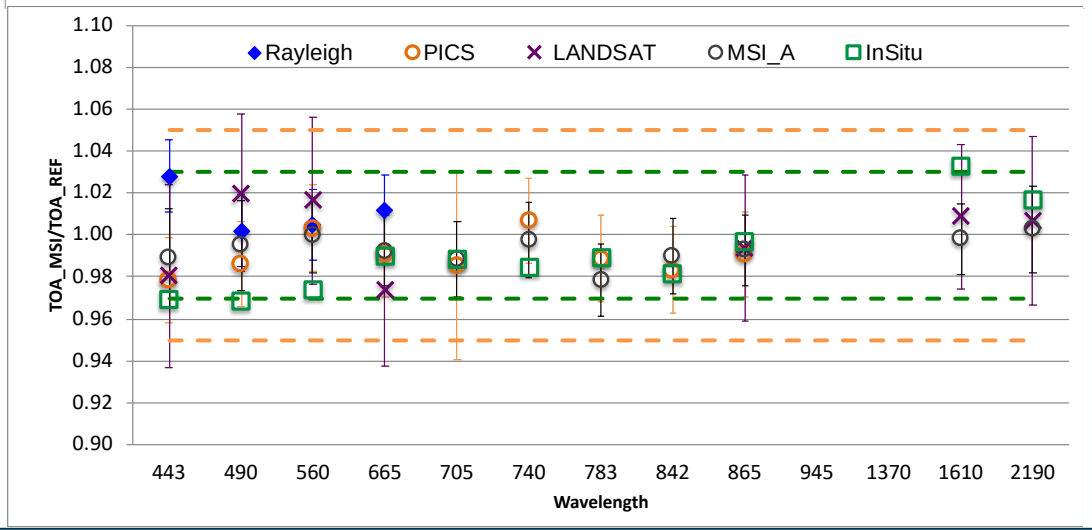
Results synthesis: Before 2022 (Bias correction)

- 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 (RadCaTS) B01, B02 & B11
- Good temporal stability (No trend detectable)
- Good consistency with similar missions (<2%)
- Slight bias of MSI-A vs MSI-B of ~1% (Corrected since 25th Jan-2022)

S2A



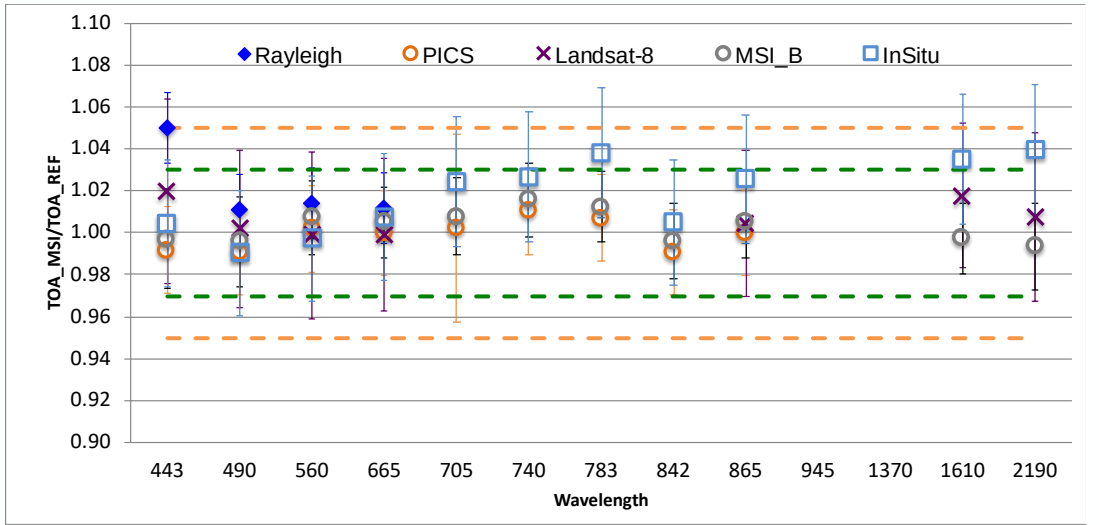
S2B



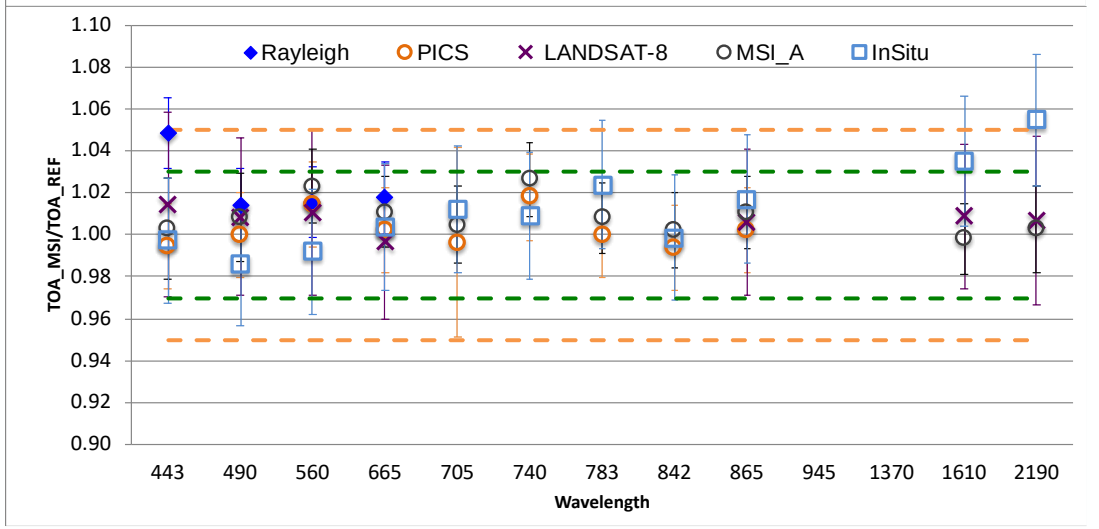
Radiometry vicarious validation activities

Results synthesis: After 2022 (Bias correction)

- **Good consistency over all the methods**
- **Results are within 3% (mission target req.)**
  - Except Rayleigh B01,
  - Except In-Situ (RadCalNet) SWIR1/2
- **Good temporal stability (No trend detectable)**
- **Good consistency with similar missions**
  - <2% over Libya4,
- **Successful MSI-B bias corrected since 25th Jan-2022**



S2A



S2B

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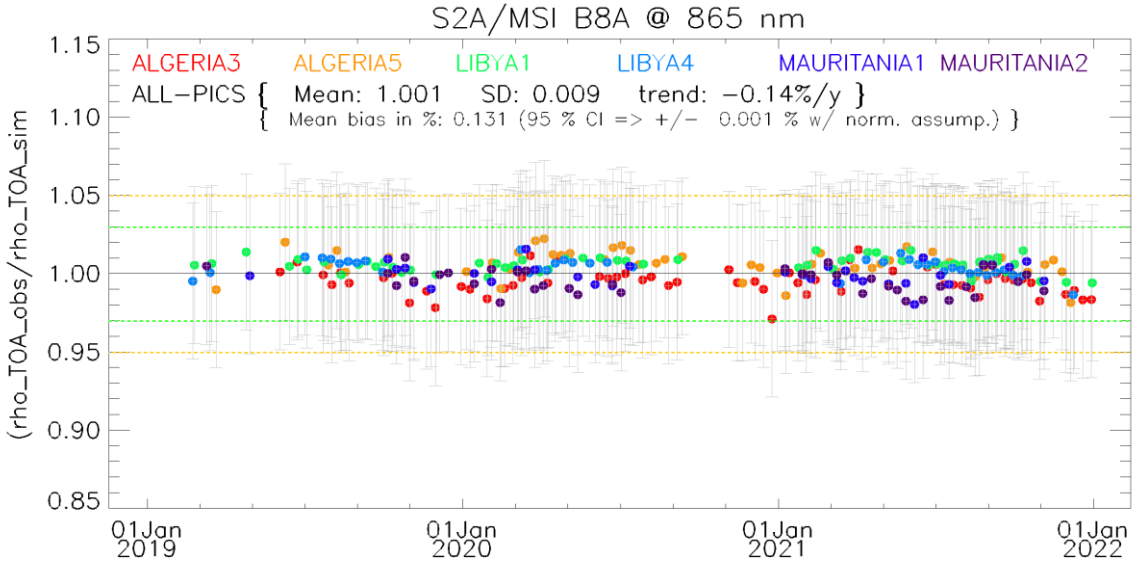
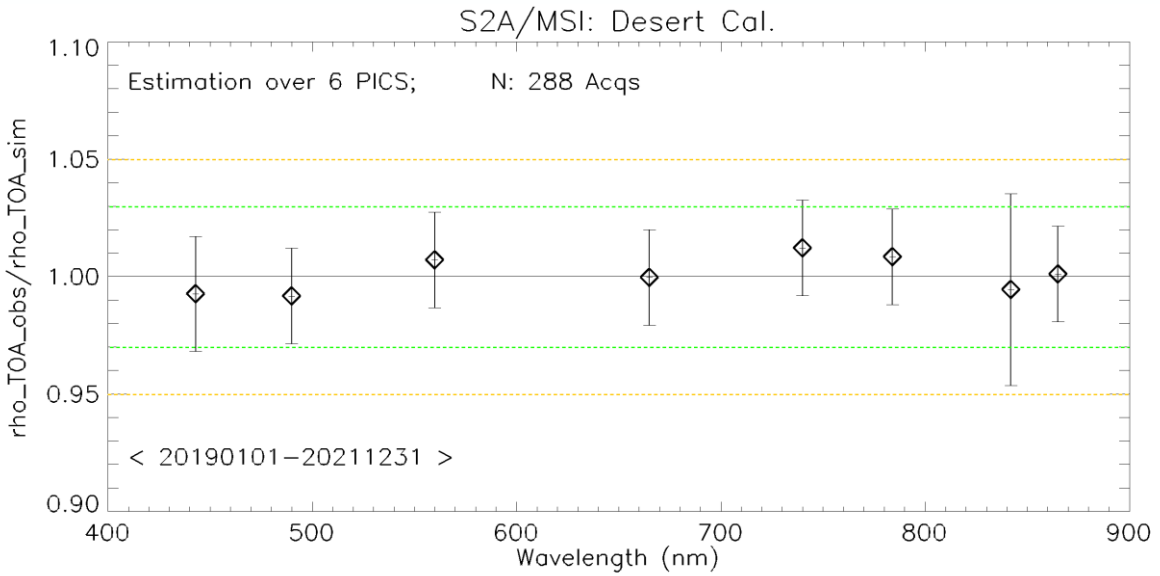
Radiometry Collection-1 verification

Radiometry vicarious validation activities

MSI-A Collection-1 over PICS

- Desert-PICS : 6 CalVal sites & period 2019-2021
  - **MSI-A: 288 Acqs**

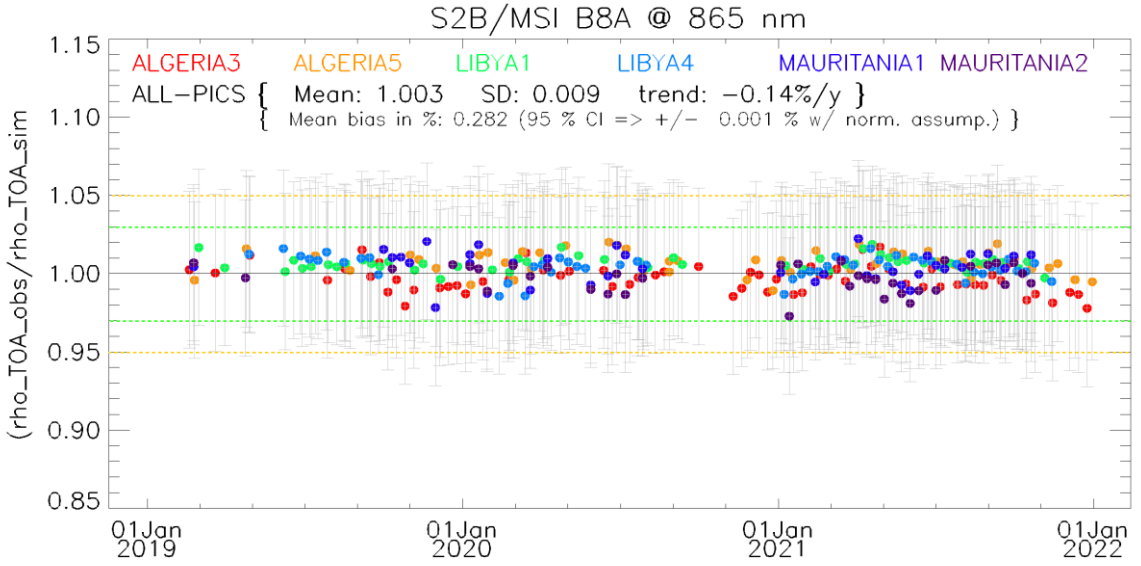


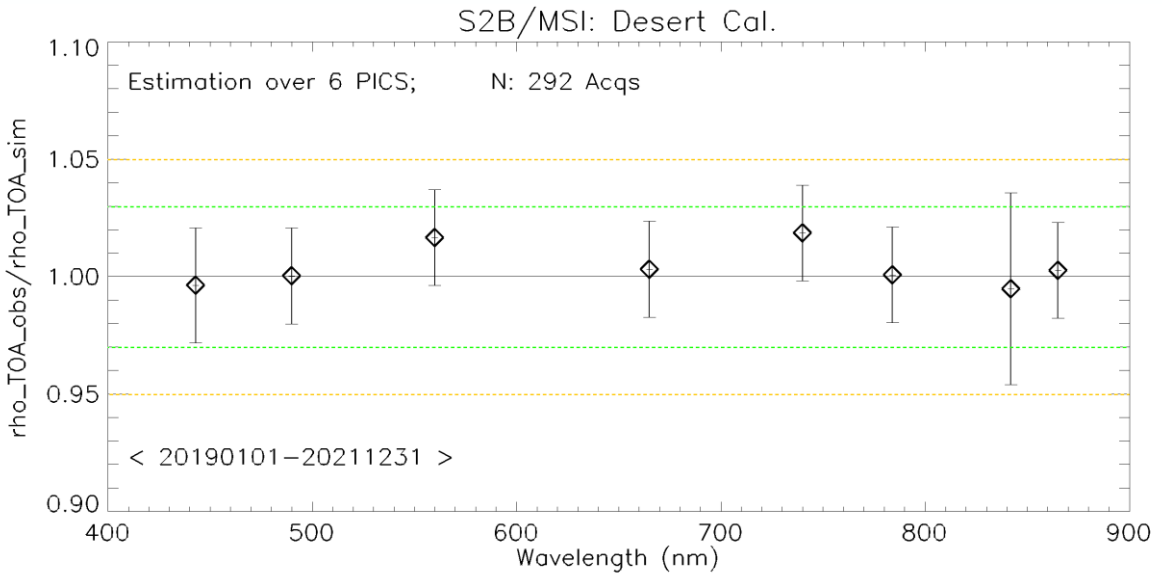


Radiometry vicarious validation activities

MSI-B Collection-1 over PICS

- Desert-PICS : 6 CalVal sites & period 2019-2021
  - **MSI-B: 292 Acqs**

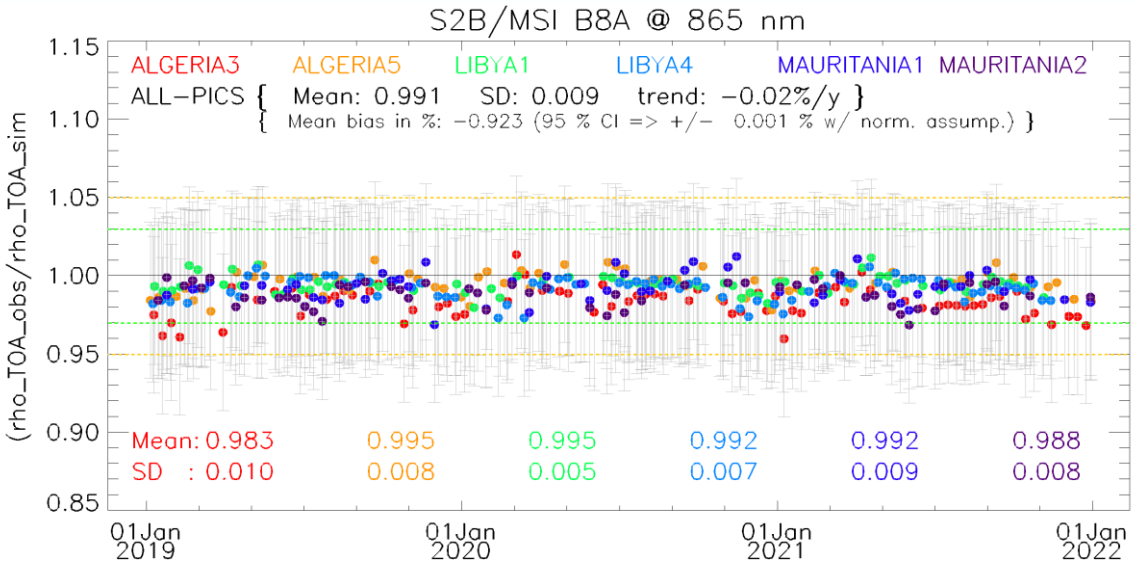


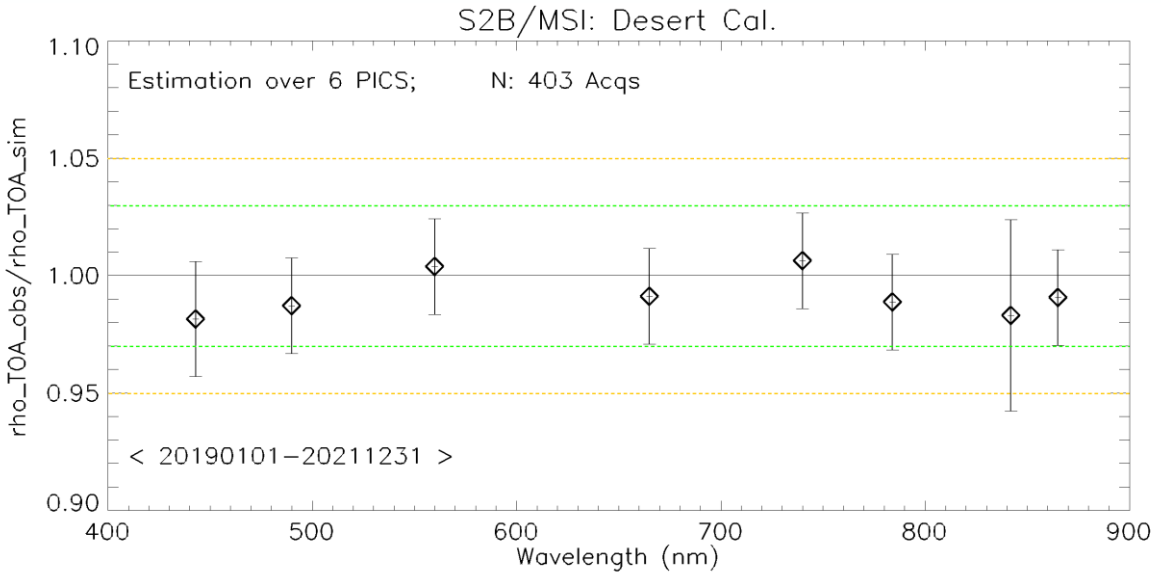


Radiometry vicarious validation activities

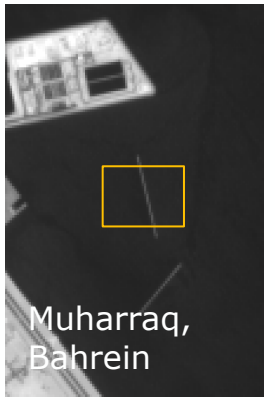
MSI-B Operational over PICS

- Desert-PICS : 6 CalVal sites & period 2019-2021
  - **MSI-B: 403 Acqs**



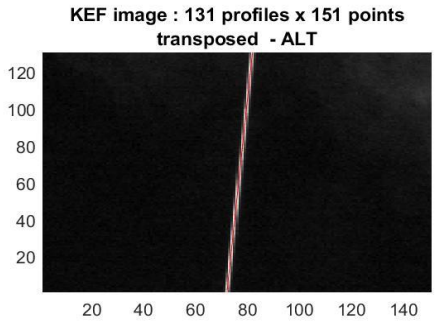


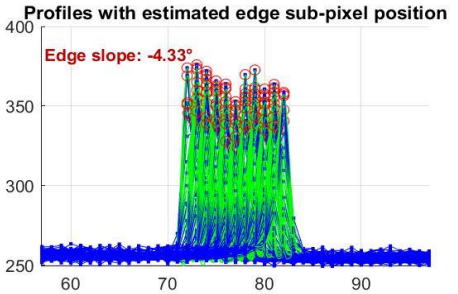
MTF measurements activities

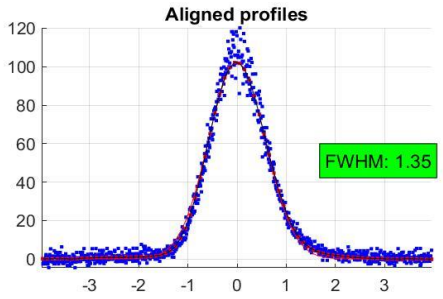


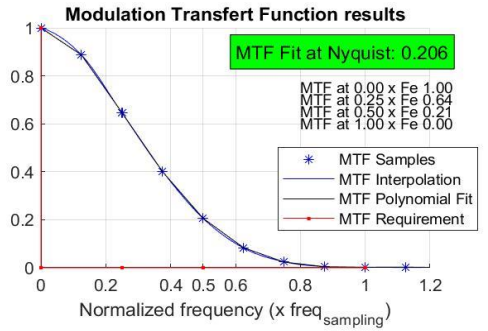
B2 ALT

Pos(l,c): 1441 2179



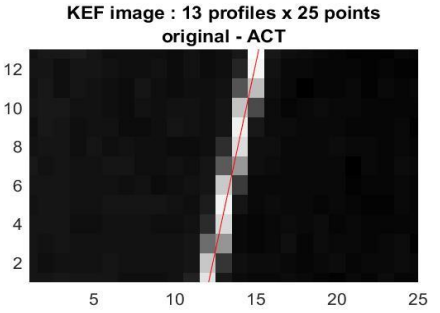


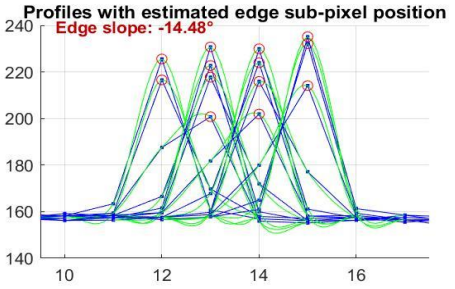


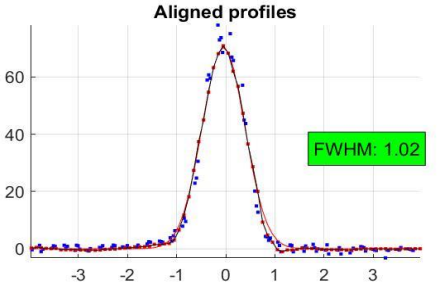


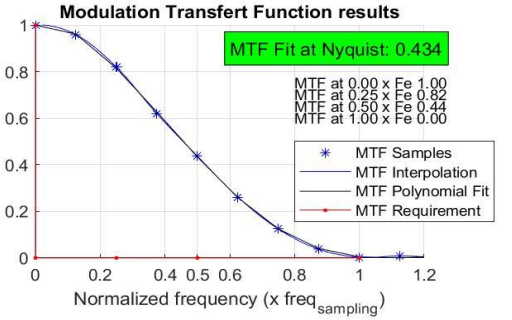
B7 ACT

Pos(l,c): 479 297





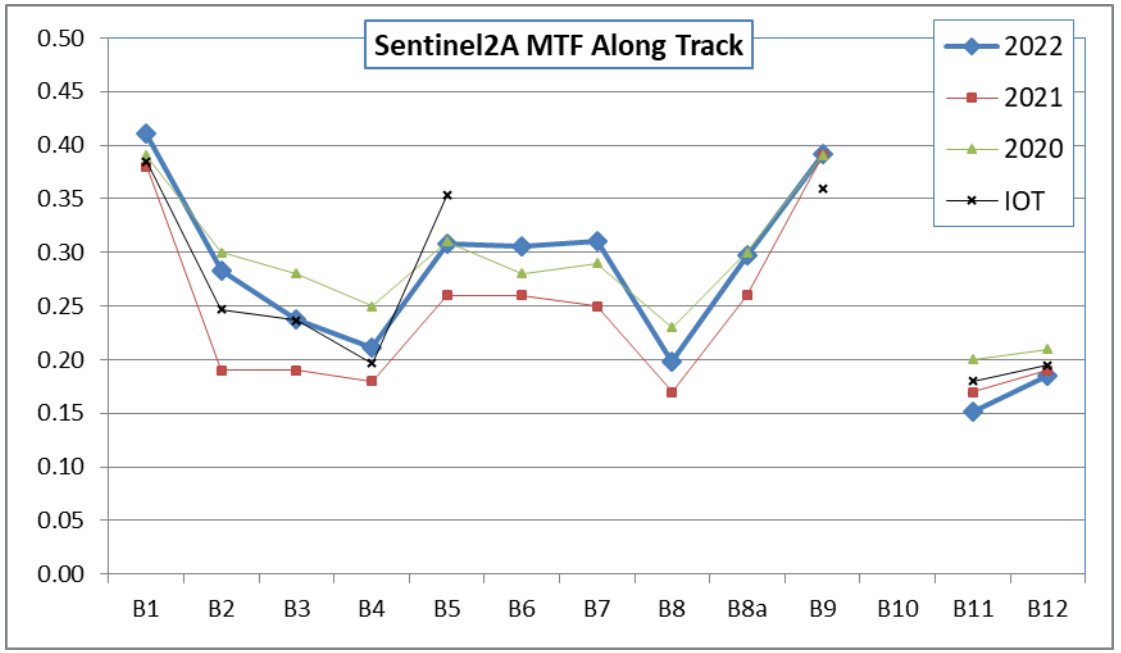


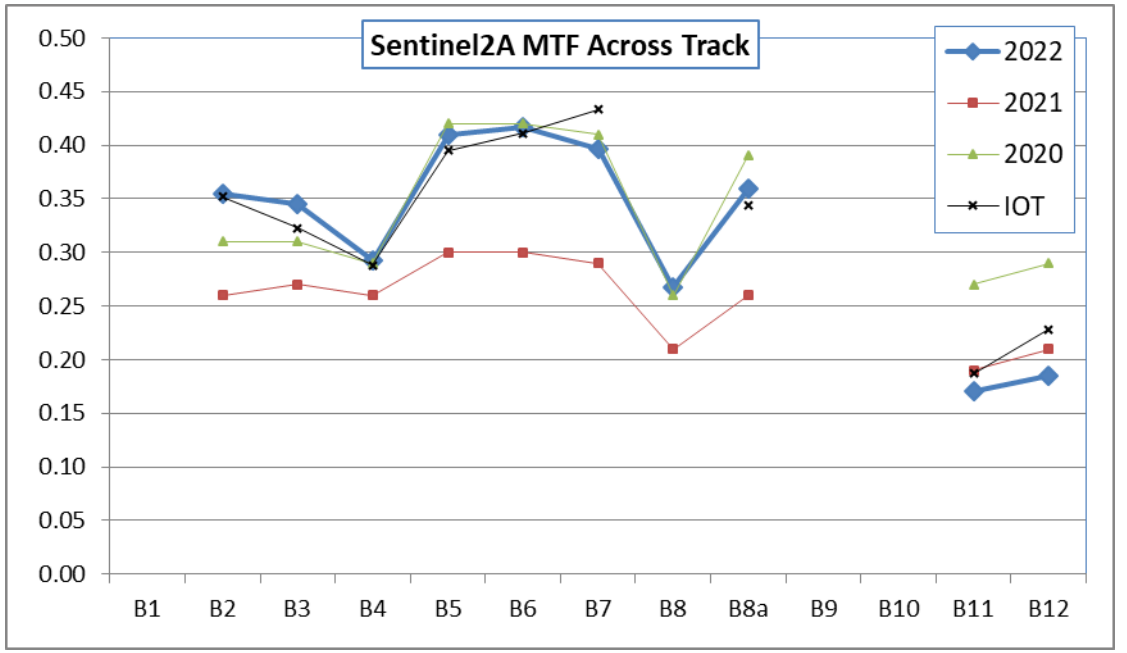


MTF measurements activities

S2A MTF measurements

- Consistent with IOT and 2020 measurements
- 2021 measurements seem biased

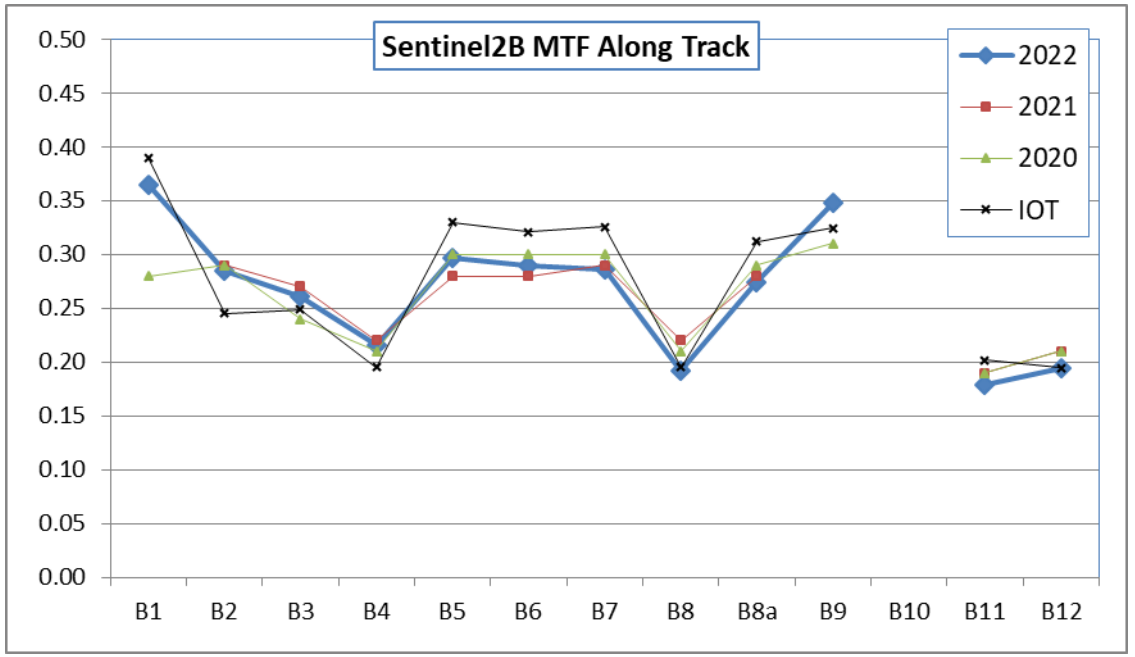


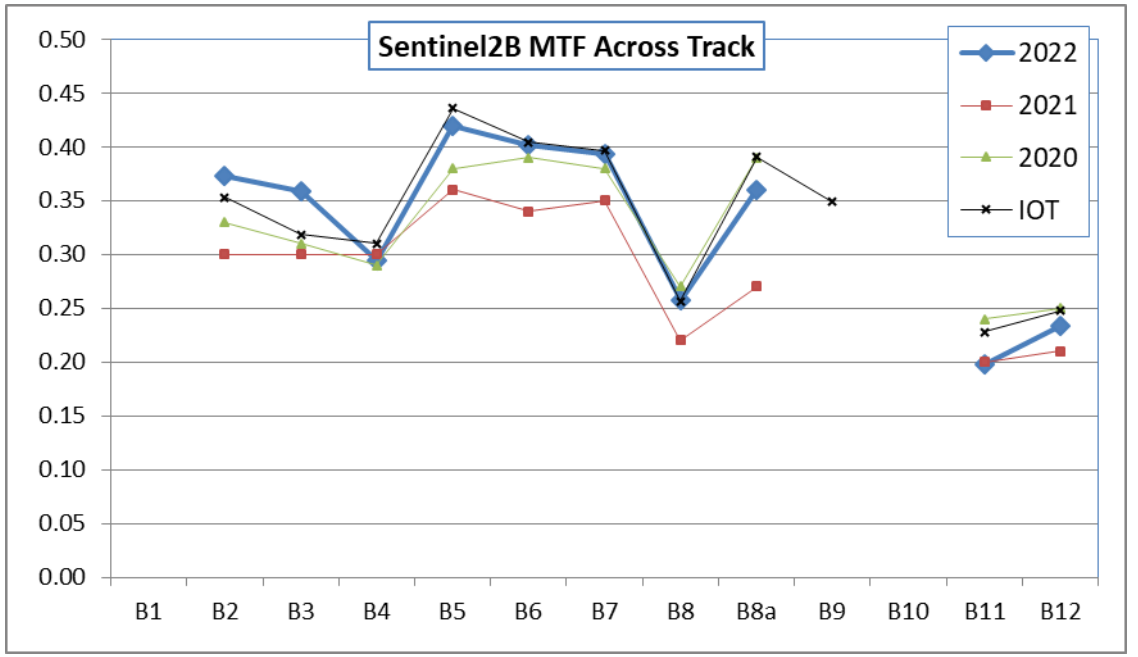


MTF measurements activities

S2B MTF measurements

- Consistent with IOT and 2020 measurements
- 2021 measurements seem biased





Evaluation of low radiance S2 SWIR data over water

Evaluation of low radiance S2 SWIR data over water

- Context
  - ✓ A potential anomaly in the calibration of the SWIR bands was reported at S2VT 2022
  - ✓ Complementary analysis
    - ➢ Report from Quinten Vanhellemont and Kevin Ruddick (RBINS) received in July 2022
    - ➢ Conclusion: no anomaly in the SWIR bands calibration

- Some results from the report
  - ✓ Comparison of TOA reflectance of MSI and OLI from near coincident overpasses:
    - ➢ MSI B11 images are noisier than OLI images → radiometric noise : key point of the initial concern

  - ✓ Comparison of BOA reflectance matchups for B3 (560 nm) between MSI and PANTHYR
    - ➢ If the atmospheric correction uses smoothed SWIR data : good concordance of BOA reflectance !

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Evaluation of low radiance S2 SWIR data over water

Mod1 = Continental aerosol model

Coastal site

No filtering of SWIR data

Smoothing SWIR data with a 0.2 x 0.2 km median filter

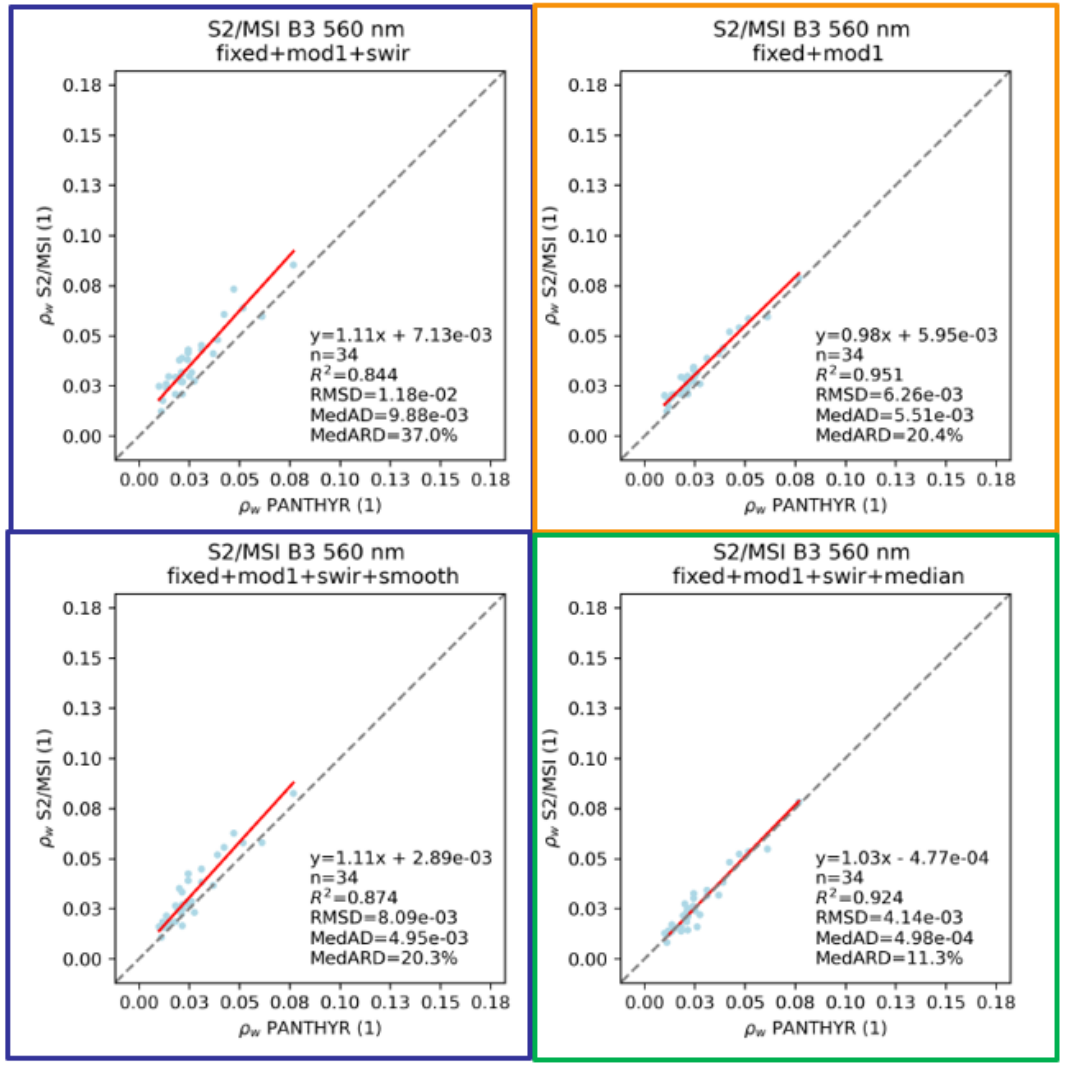

Figure 8: PANTHYR/MSI matchups with MSI processed MOD1 (maritime) with unfiltered SWIR (top left), without SWIR (top right), and using 200x200 metres median filter (bottom left) and bottom right subscene (3x3 km) median filter (bottom right).

Without using SWIR data

Smoothing SWIR data with a 3 x 3 km median filter

➔ Very good concordance

Radiometry vicarious validation activities

Conclusions:

- ✓FPN results for S2A and S2B meet the requirements in all Bands
- ✓Estimated SNR exceeds specifications and are temporally stable
- ✓Good consistency over all the vicarious methods
- ✓Results are within 3% (mission target req.)
- ✓Maximum discrepancy is observed over

  Rayleigh B01; Matchups with LS-8 B01 & B02; Matchups with Ground-measurements B01, B02 & B11
- ✓Good temporal stability over PICS (No trend detectable)
- ✓Good consistency with similar missions (<2%)

- ✓ Good alignment of MSI-A vs MSI-B (bias <1% over 04-2023)
- ✓ Consistent results over the radiometry of the Collection-1 reprocessing.
- ✓ MTF: minimum specified value (0,15): ok for all bands
- ✓ MTF: maximum specified value (0,30 for 10 & 20 m bands and 0,45 for 60m bands):
  - ✓ OK for all bands (except red edge ones)
- ✓ MTF Stability: Should be better than 10% peak-peak :
  - ✓ OK wrt IOT measurements (ADS ones)
- ✓ No anomaly in the SWIR bands calibration

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THANK YOU FOR YOUR ATTENTION

RADCATS dataset were provided by the NASA Landsat Cal/Val Team as part of the ESA expert users effort
Thanks to RadCalNet team for providing the dataset
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Funded by the EU and ESA

European Union

Radiometry vicarious validation activities

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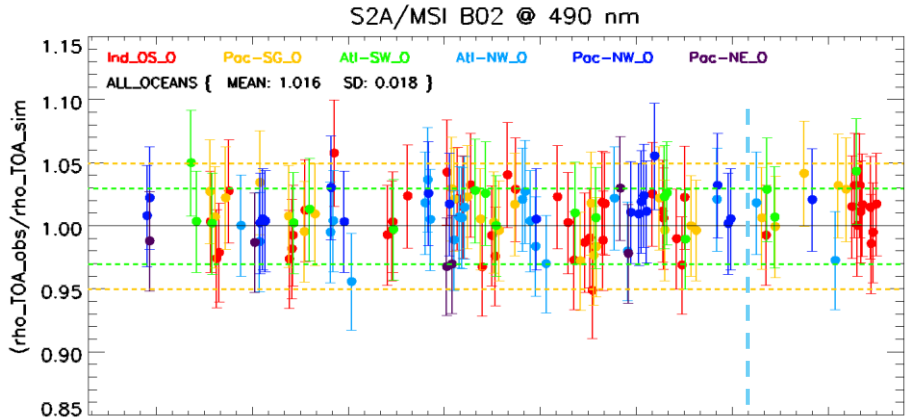
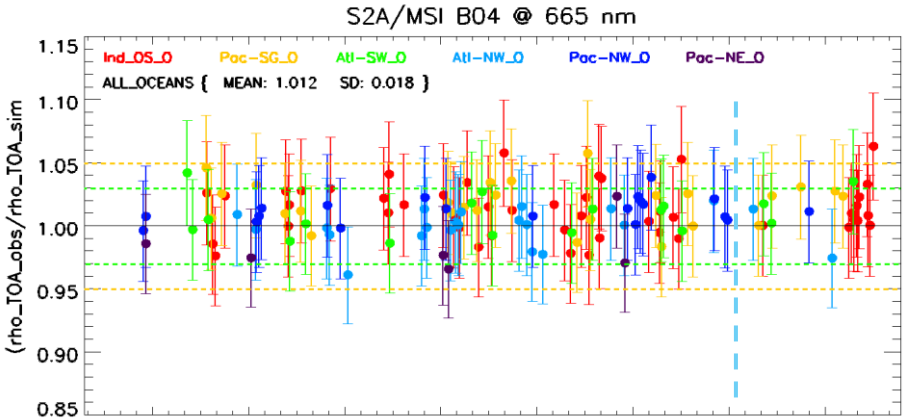
OPT-MPC Optical Mission Performance Cluster (Copernicus Sentinel)

ARGANS

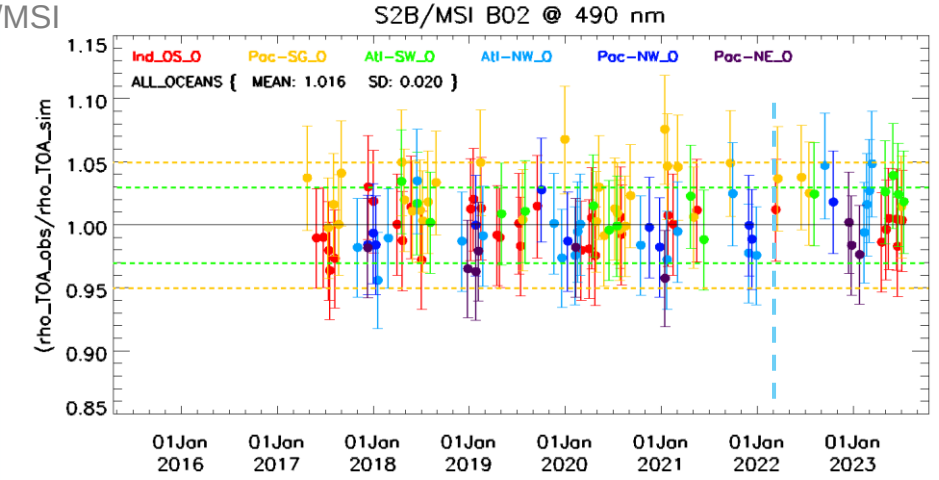
RAYLEIGH METHOD: 6 CalVal sites & time-series up to July 2023

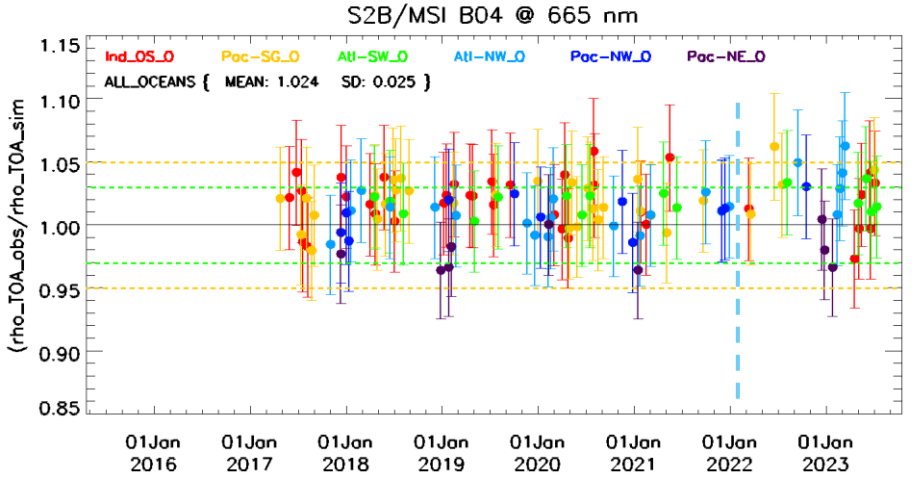
S2A/MSI





S2B/MSI





Wavelength (nm)	MSI-A #22 Acq	MSI-B #25 Acq
443	1.046	1.045
490	1.016	1.016
560	1.016	1.014
665	1.012	1.024

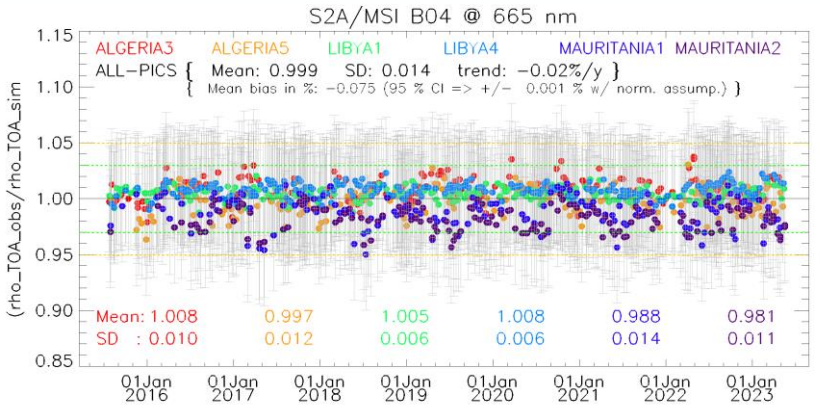
Averaged:
Jan-2022 - July 2023

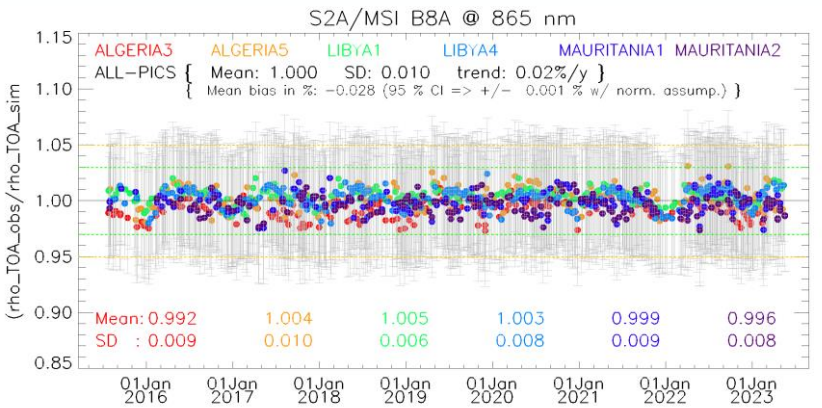
Radiometry vicarious validation activities

Desert-PICS Method : 6 CalVal sites & time-series up to May 2023

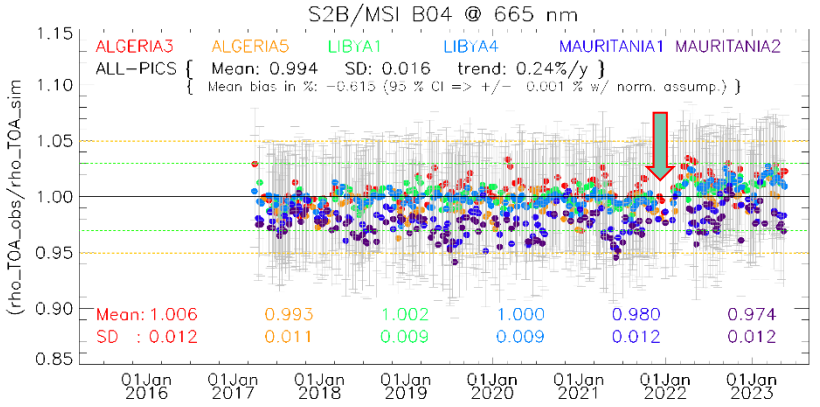
- **S2A/MSI**; 1070 acquisitions used; VNIR are within 3% ; No detectable trend
- **S2B/MSI**; 815 acquisitions used; VNIR are within 3% ; No detectable trend

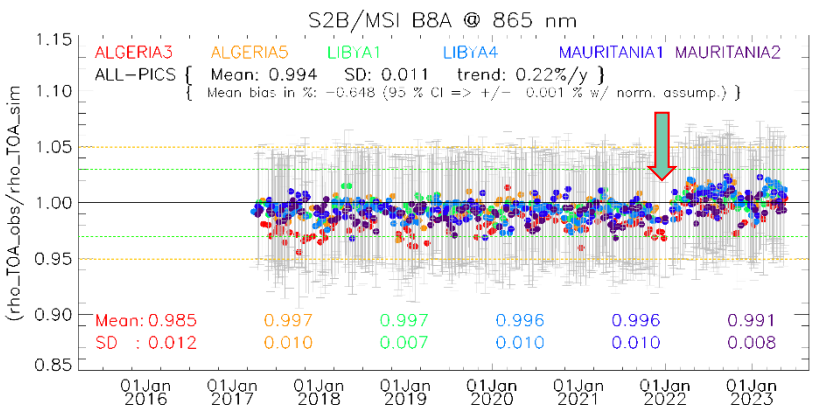
S2A/MSI





S2B/MSI





Wavelength (nm)	MSI-A #1070 Acq	MSI-B #815 Acq
443	0.991	0.983
490	0.993	0.990
560	1.005	1.006
665	0.999	0.994
705	NA	NA
740	1.011	1.009
784	1.007	0.991
842	0.992	0.986
865	1.000	0.994

Radiometry vicarious validation activities

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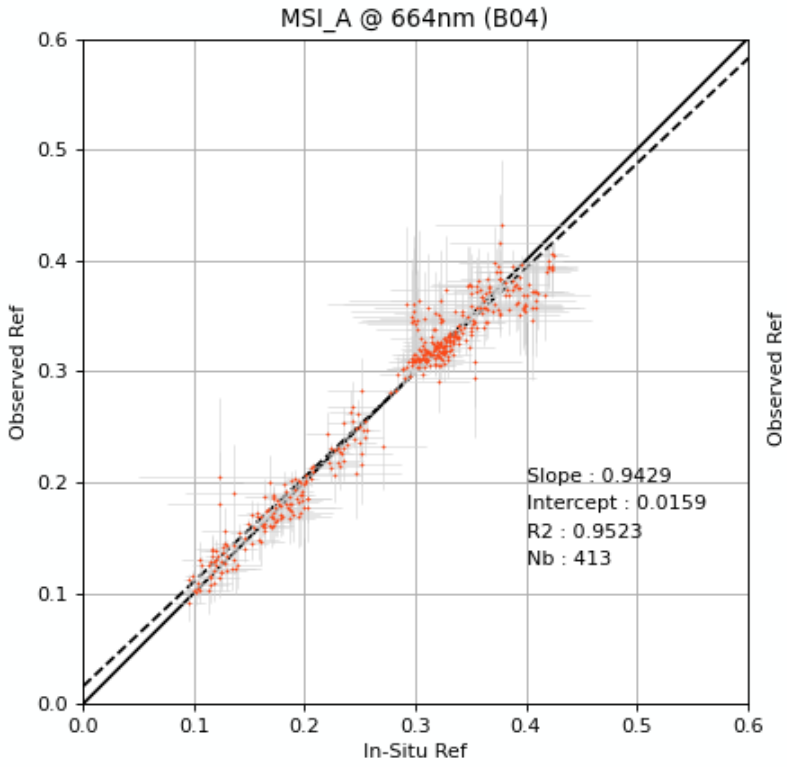
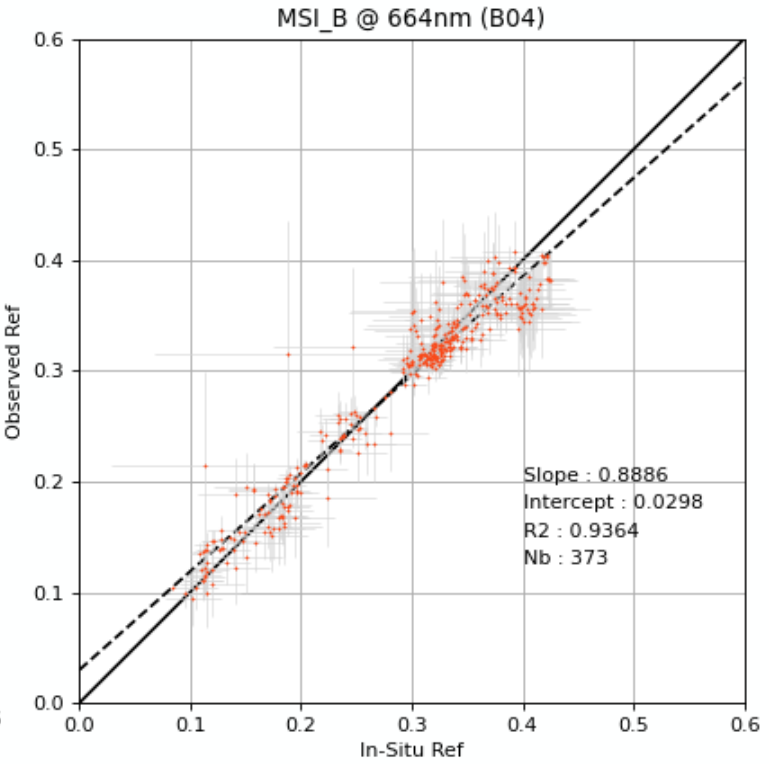
In-Situ measurements: over RadCalNet dataset up to June. 2023: (TOA reflectance, NADIR-view)

- **About 430** overpasses **S2A** and **380** overpasses **S2B**
- ROI: 0.1°x0.1° latitude x Longitude
- All bands are within 5% (excluding B09, B10).

CEOS RadCalNet





Evaluation of low radiance S2 SWIR data over water

- From Quinten Vanhellemont ‘s report

5. Conclusions

– Due to the lower SNR of MSI compared to OLI, the MSI observations contain a wider distribution of ρ_t values. Selecting the lowest value from this wider distribution will result in lower ρ_t compared to OLI, and hence a lower estimate of τ_a 550 nm. **This is a issue related to the SNR and DSF algorithm construction, and not MSI calibration.**

– By spatially averaging the data, MSI observations are closer to OLI, even though even at 3x3 km the average is in many cases lower for MSI than for OLI, with a mean average difference of -1.8e-4 and median difference of -1.6e-4, i.e. up to 2 DN in the MSI L1C, with occasional larger differences.

– From the matchup analysis it seems that the filtering of SWIR bands enables their use in ACOLITE/DSF processing, and that the residual differences described above for ρ_t and hence τ_a do not significantly impact the performance. **This noise filtering addresses the issue highlighted in Vanhellemont (2020) and an update of the treatment of the SWIR in ACOLITE/DSF may improve results in general.** The ACOLITE/DSF processing of Landsat also benefits from some SWIR smoothing.