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Radiometric Intercomparisos of Sentinel-2 MSI, Sentinel-3 OLCI and Landsat OLI using Deep Convective Couds

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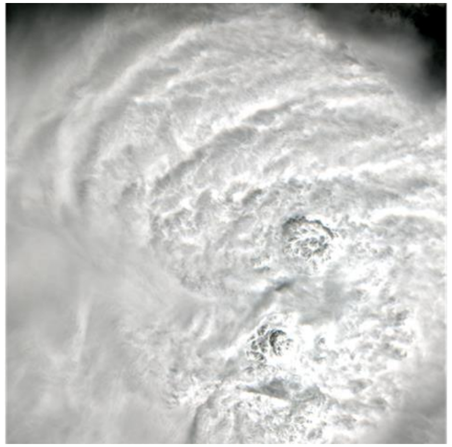
Deep Convective Clouds for calibration monitoring

- DCC used for over two decades (*Vermote and Kaufman, 1995; Hu et al. 2004; Doelling et al. 2004…*)

- DCC properties:
  - ✓ high altitude (close to tropical tropopause)
  - ✓ high occurrence in the tropics
  - ✓ bright and white (high radiance, spectrally flat)
  - ✓ very vertically-extended, high optical thickness (low/no signal from beneath the cloud)
  - ✓ can be very extended horizontally
  - ✓ nearly Lambertian
- Statistically invariant (short-term)



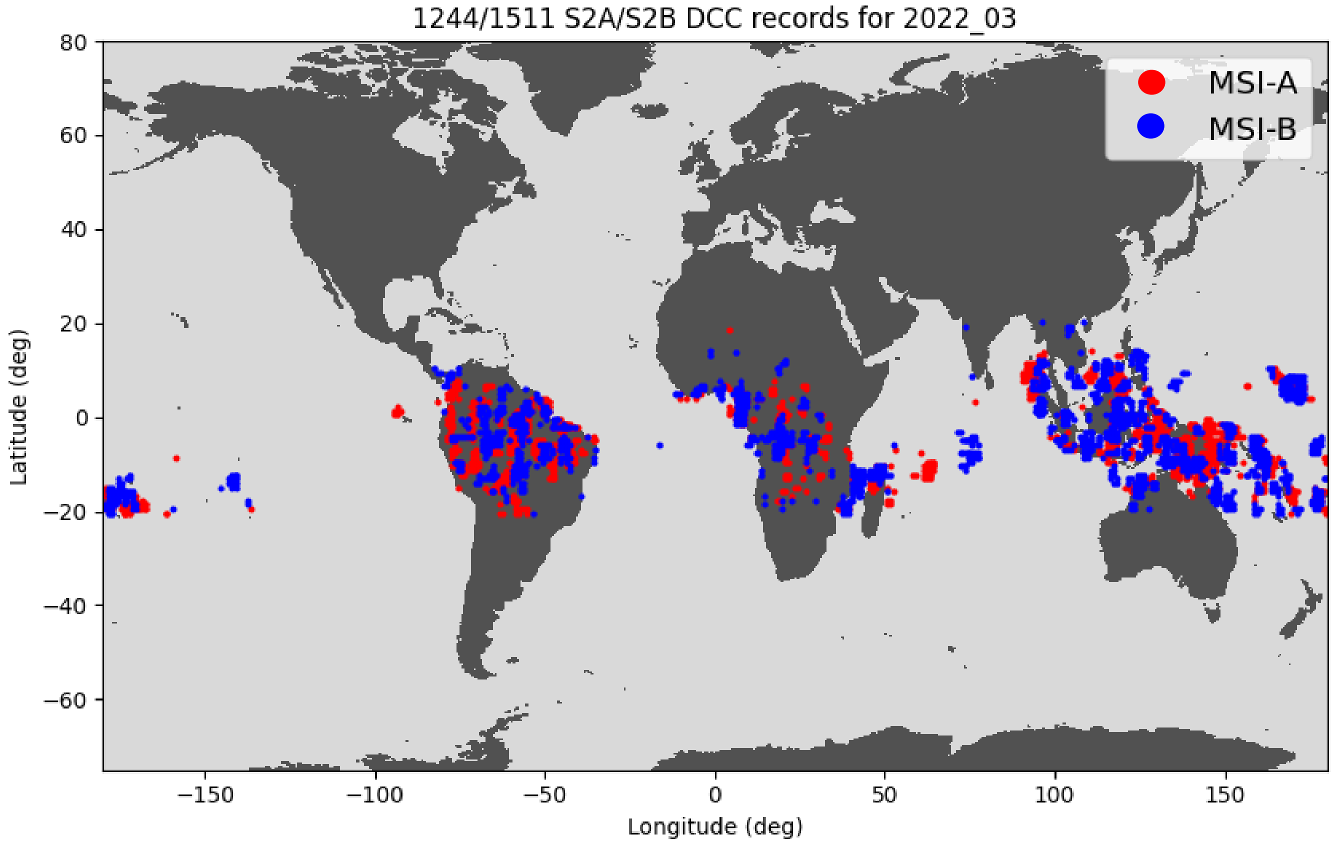
DCC extending over a complete S2 tile (~100x100 km²)

Expedition Crew 16, ISS, Image Science and Analysis Laboratory, Johnson Space Center

Methodology

Data pre-selection

- Inter-tropical region: high occurrence, low directional effects
- > 90 % cloud cover
- Pixels with ρ > 0.2 in cirrus band
  - ✓ B10 for **MSI A/B**, B9 for **OLI / OLI-2**
- Cold clouds
  - ✓ S8 (10.8 µm) SLSTR band, for **OLCI A/B**



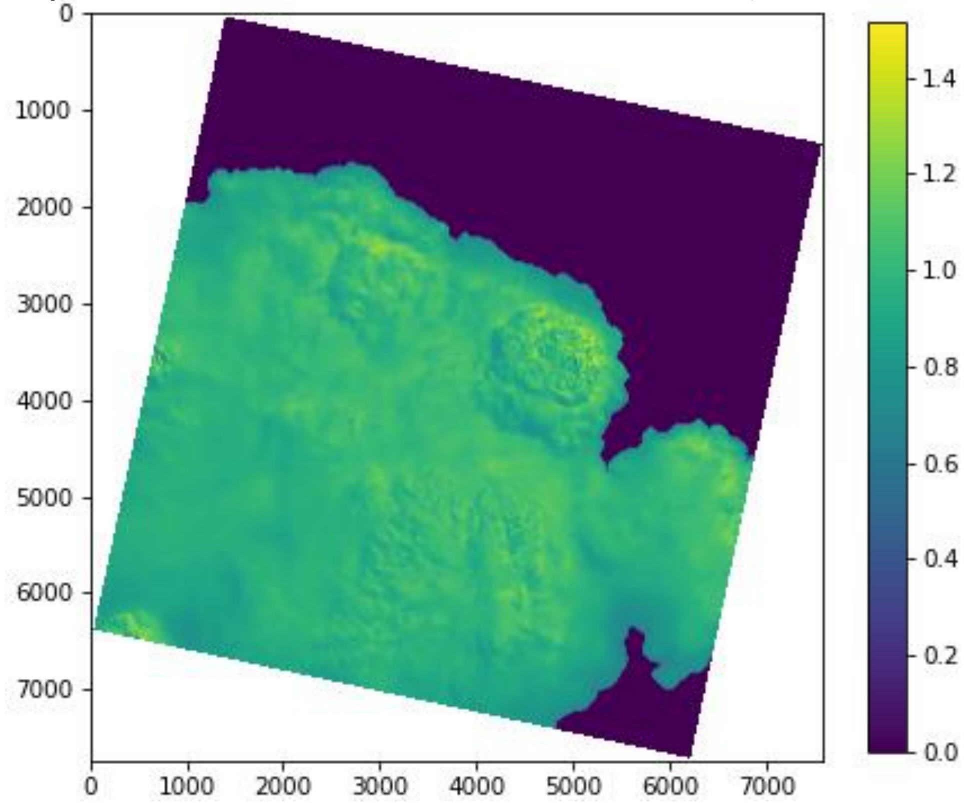
Example localization of the DCC products for Sentinel-2 MSI, March 2022.

Methodology

DCC cluster selection

- Based on thresholds of reflectances
  - ✓ **MSI A/B**, B10 (cirrus) > 0.4 (high-altitude clouds) & B8A (NIR) > 0.7 (focus on high reflectances)
  - ✓ **OLI / OLI-2**, B9 (cirrus) > 0.4 & B5 (NIR) > 0.7
- Based on brightness temperature
  - ✓ **OLCI A/B**, BT < 225 K on SLSTR 10.8 µm band

Top-of-DCC reflectances in band 2 (blue band)

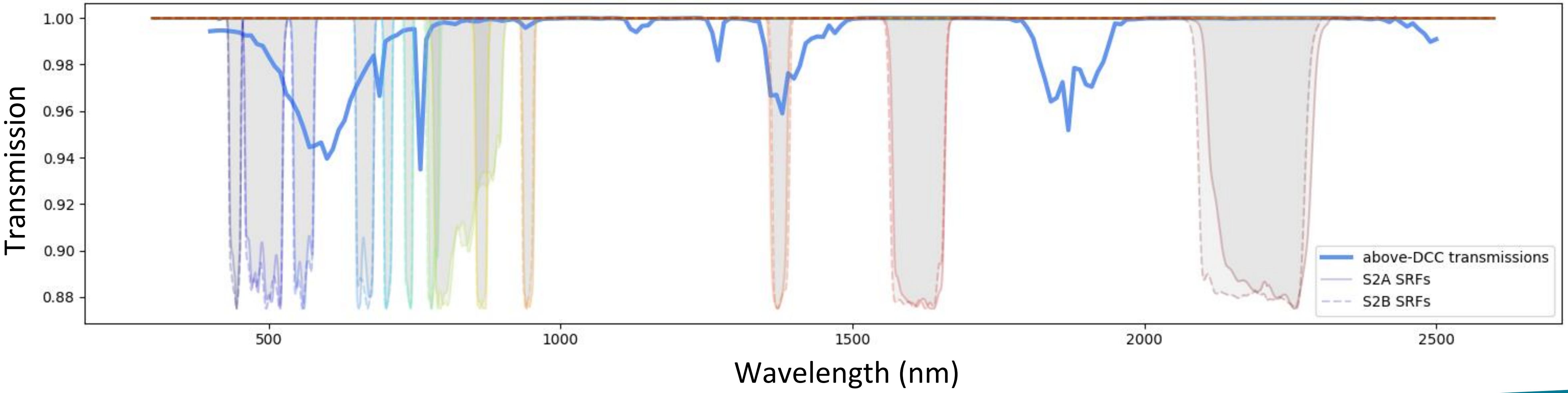


Identified DCC cluster, example of Landsat-8 LC08_L1TP_108061_20220715_20220725_02_T1, July 2022

Correction from above-DCC gaseous transmissions

- Transmissions generated using ARTDECO (*MILADI, L., DUBUISSON, P., COMPIEGNE, M., & LABONNOTE, L. Atmospheric Radiative Transfer Database for Earth and Climate Observation (ARTDECO)*)
- As a function of O_3 concentration

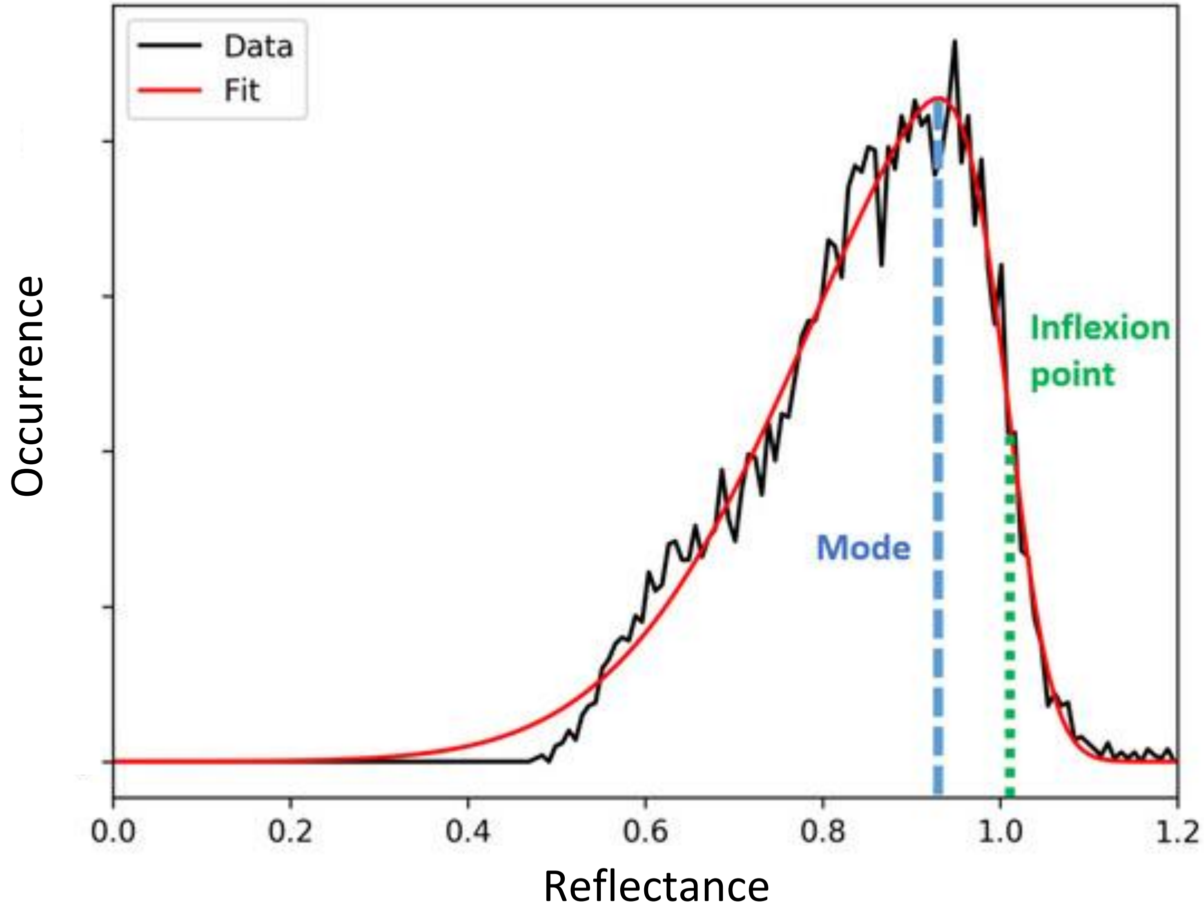
$$\rho_{DCC}(\theta_s, \theta_v, \Delta\varphi, \lambda) = \rho_{\boldsymbol{TOA}}(\theta_s, \theta_v, \Delta\varphi, \lambda) \;/\; T_{gas}(\theta_s, \theta_v, \lambda)$$



Methodology

Extraction of a reflectance indicator

- For each product and band: PDF from top-of-DCC reflectances
- 1 month → 5 batches
- Accumulation of PDFs
- Skewed-Gaussian model fit
- Post-mode inflexion point extraction



Example PDF of the DCC reflectances from OLCI. Lamquin et al., 2020.

OPT-MPC
Copernicus Sentinel
Optical Mission Performance Cluster
ACRI ST

Methodology

Extraction of a reflectance indicator

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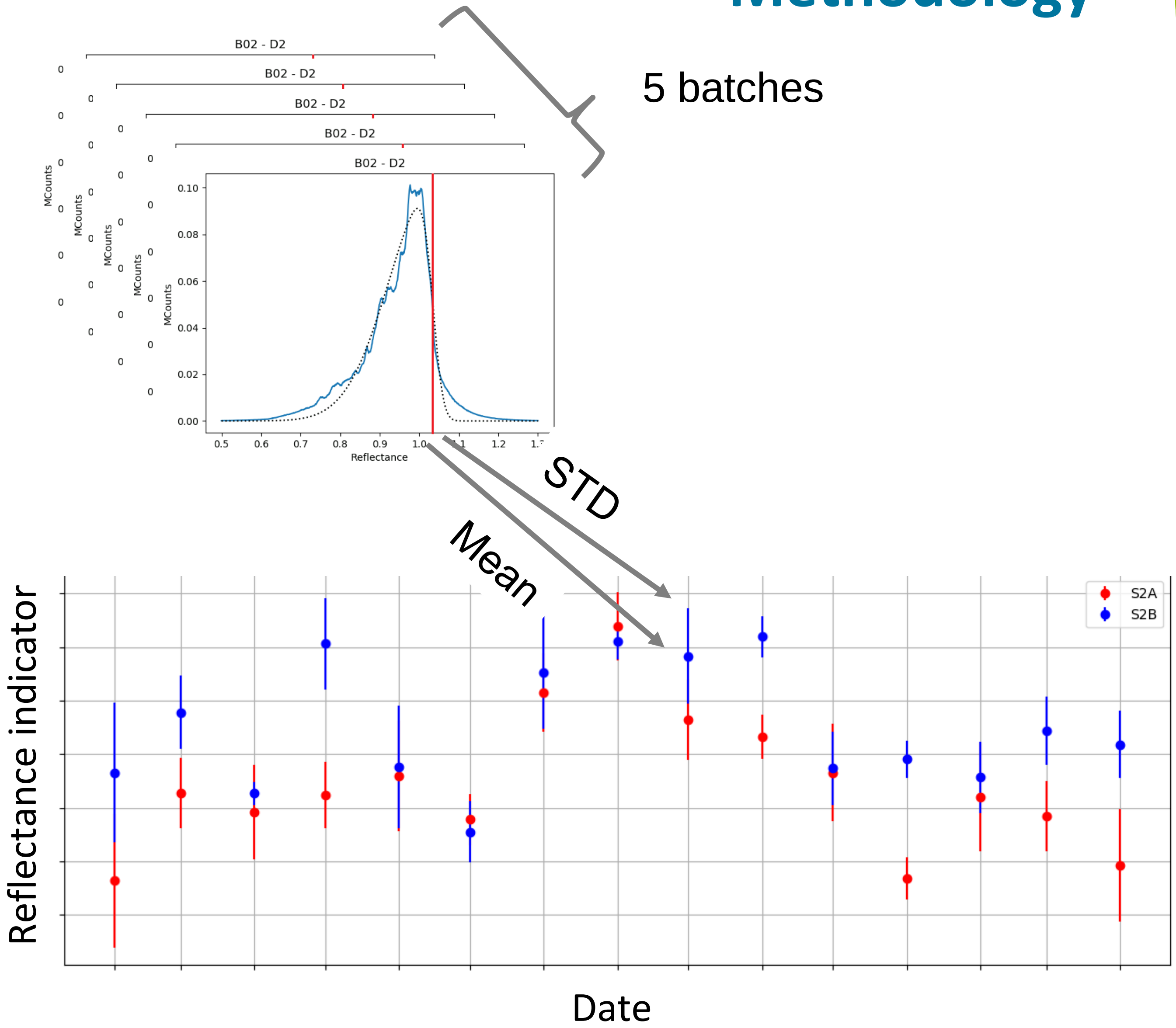
- Accumulation of PDFs
- Skewed-Gaussian model fit
- Post-mode inflexion point extraction
- Mean of 5 inflexion points: reflectance indicator
- STD of 5 inflexion points: uncertainty



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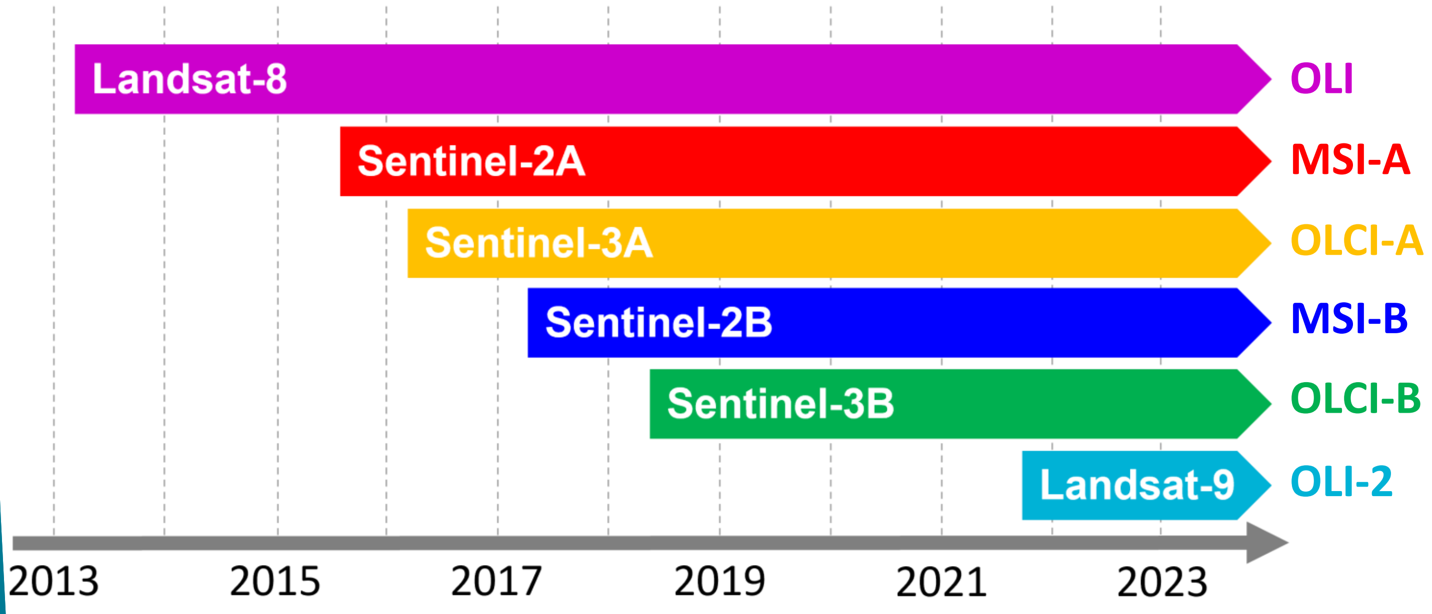
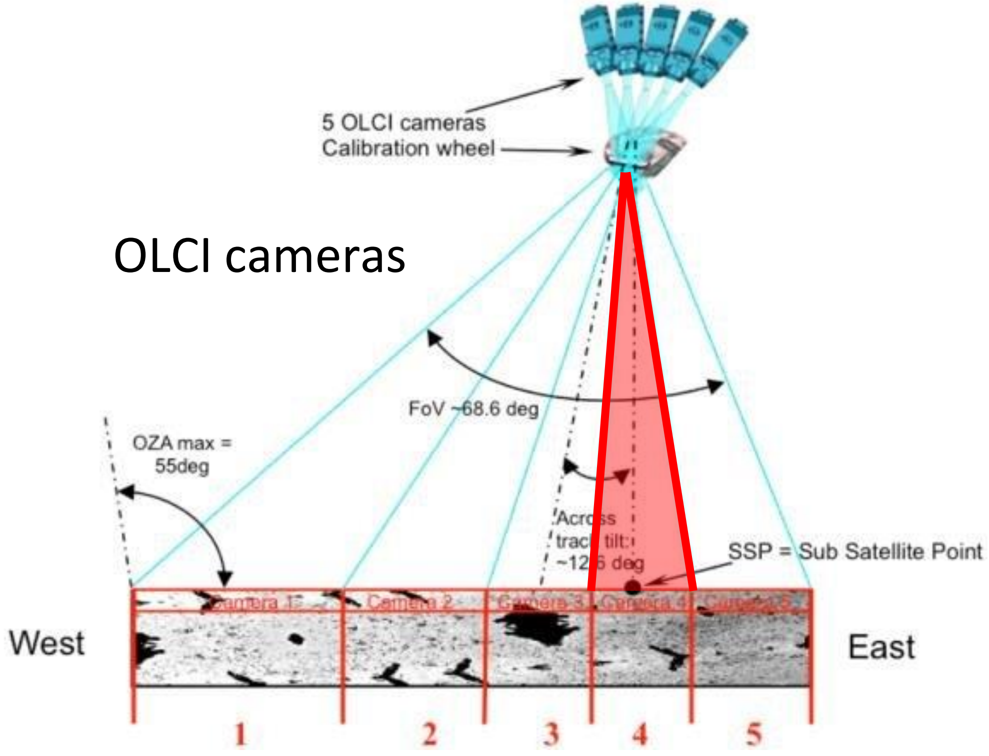
Objectives definition

Application of DCC method to 6 multispectral sensors



OLCI cameras

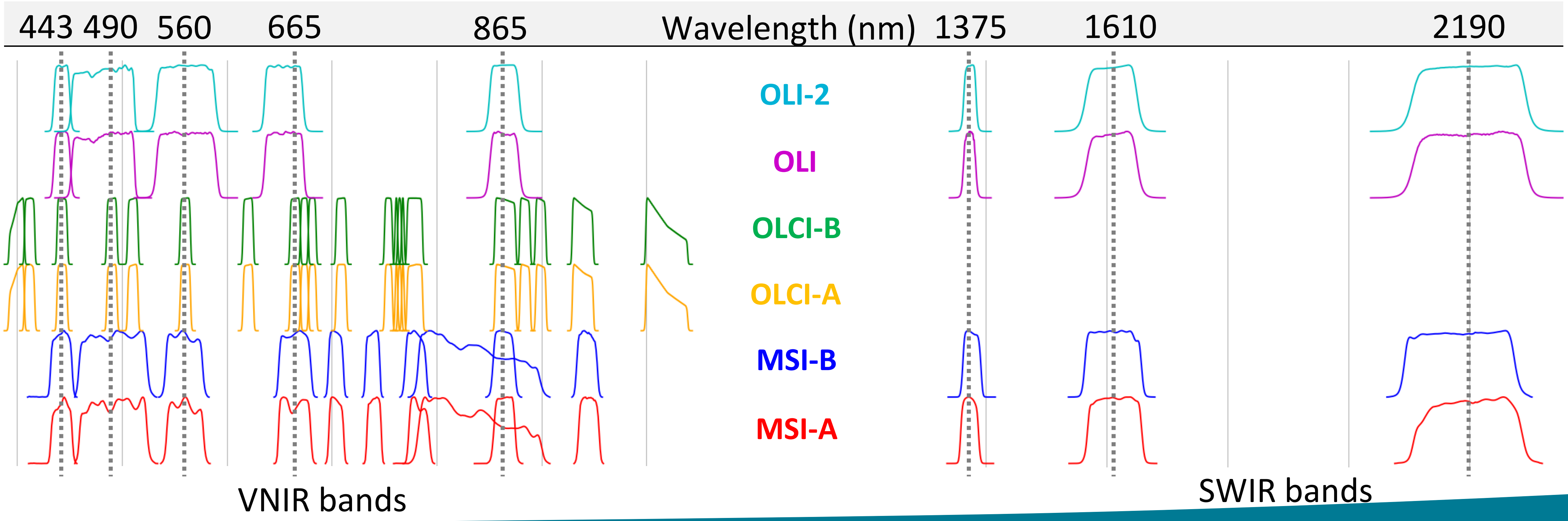


- 185, 290 and 1270 km swath for Landsat, S2 and S3
  - ✓ Use of near-nadir camera only for S3 (cam-4)
- Common time-period (early 2022 to early 2023): intercomparisons in this range

Objectives definition

Bands of interest

- Focus on several “comparable” bands
  - ✓ 5 sets in the VNIR (for all sensors)
  - ✓ 3 sets in the SWIR (OLCI excepted)



Objectives are:

- Follow the intercalibration of each pair of “twin” sensors
- Follow the relative levels of the comparable bands of the different missions
- Detect a potential drift

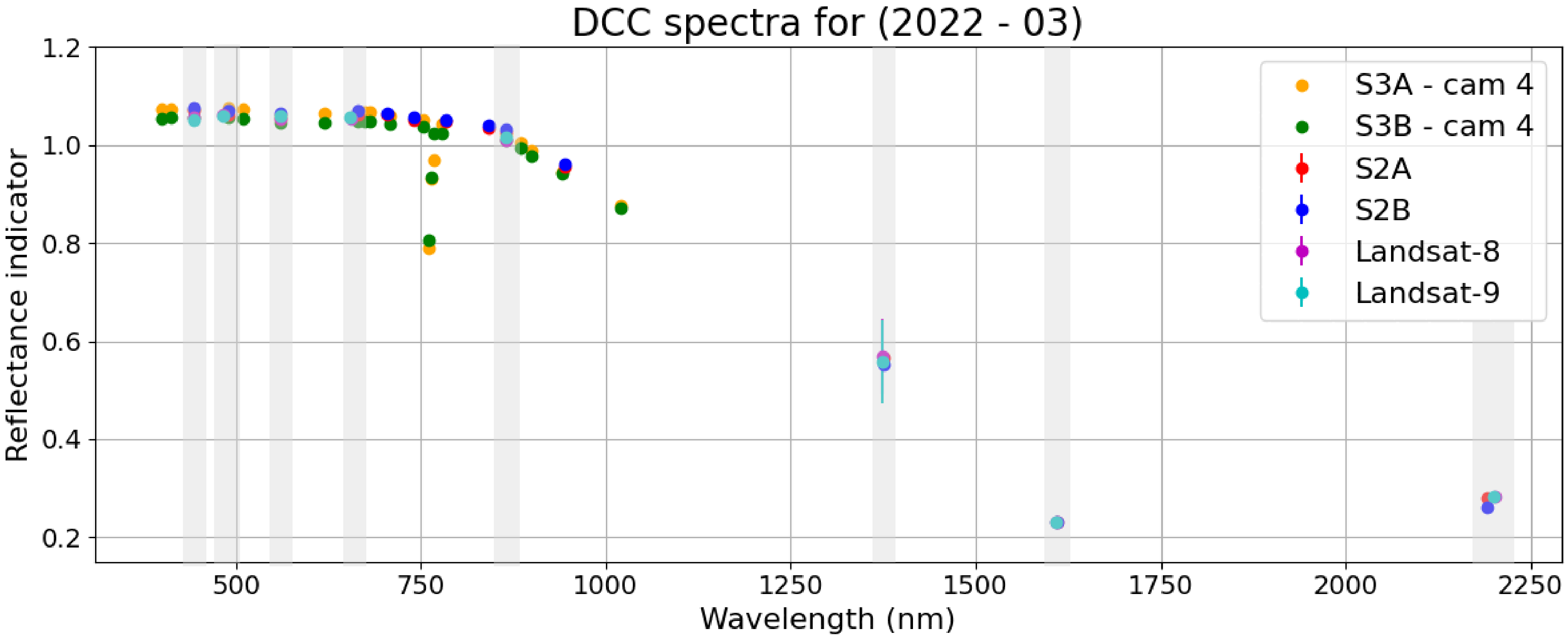
Objectives aren't:

- Provide an absolute level of radiometric calibration
- Rank the sensors in terms of radiometric accuracy

Results

Average spectra

OLI-2
OLI
OLCI-B
OLCI-A
MSI-B
MSI-A



Sensor-wise:

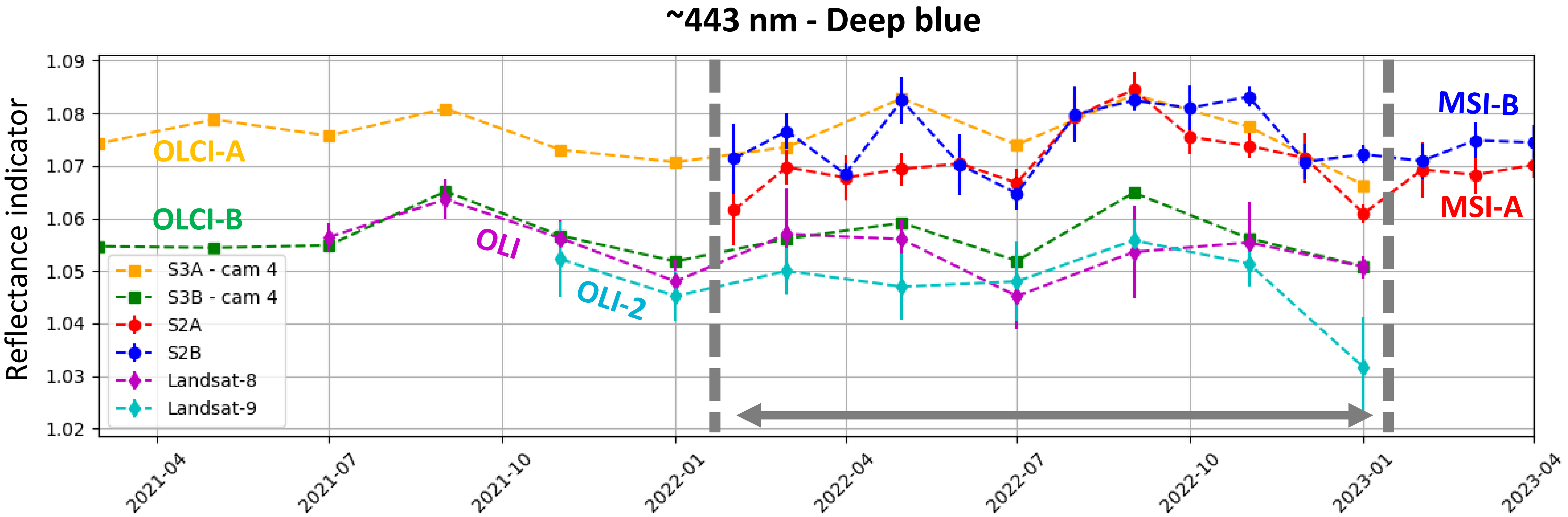
- VNIR: 3 % dispersion (except 01/2023 443nm, ~4%)
- Alignment of 1610 nm SWIR band ~correct
- More dispersion in cirrus and last SWIR band

Temporally:

- Each sensor's VNIR band within 2 %
- More variability in the SWIR (cirrus band)

Results

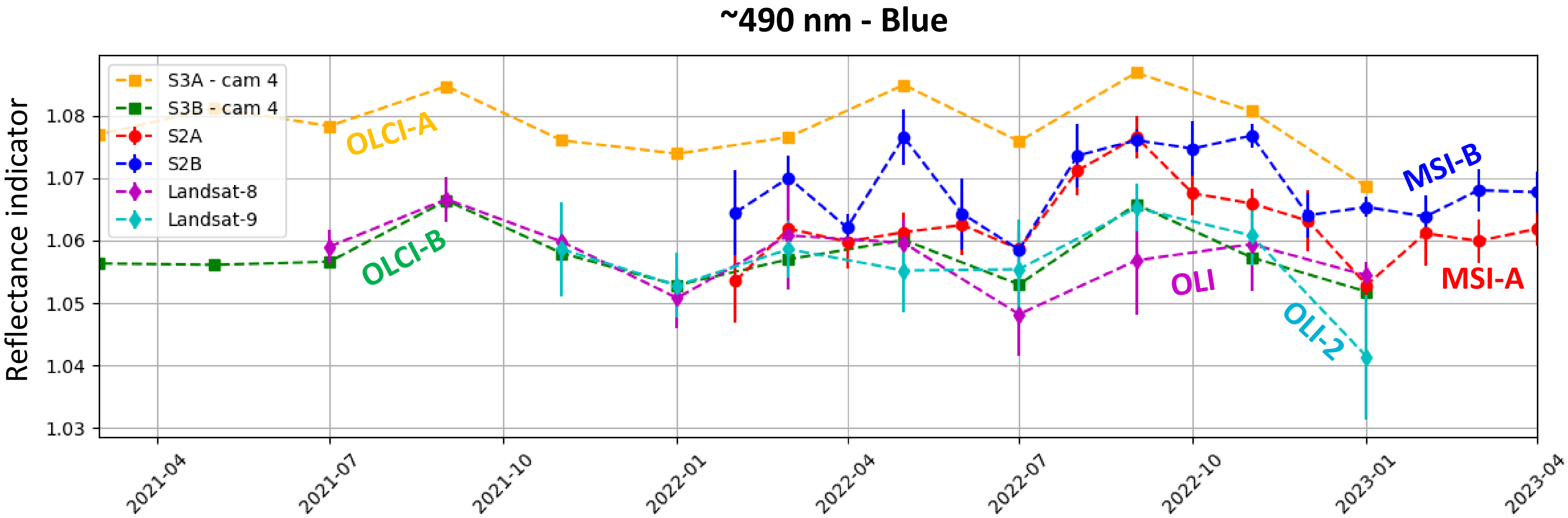
Time-series



- OLCI-A and OLCI-B : 1.5 to 2% stable bias
- MSI-A and MSI-B ~aligned with OLCI-A
- OLI and OLI-2 ~aligned with OLCI-B
- MSI-A and MSI-B within 1%
- OLI and OLI-2 within 1% (except 01/2023)
- Overall dispersion of 3% max. (except 01/2023)

Results

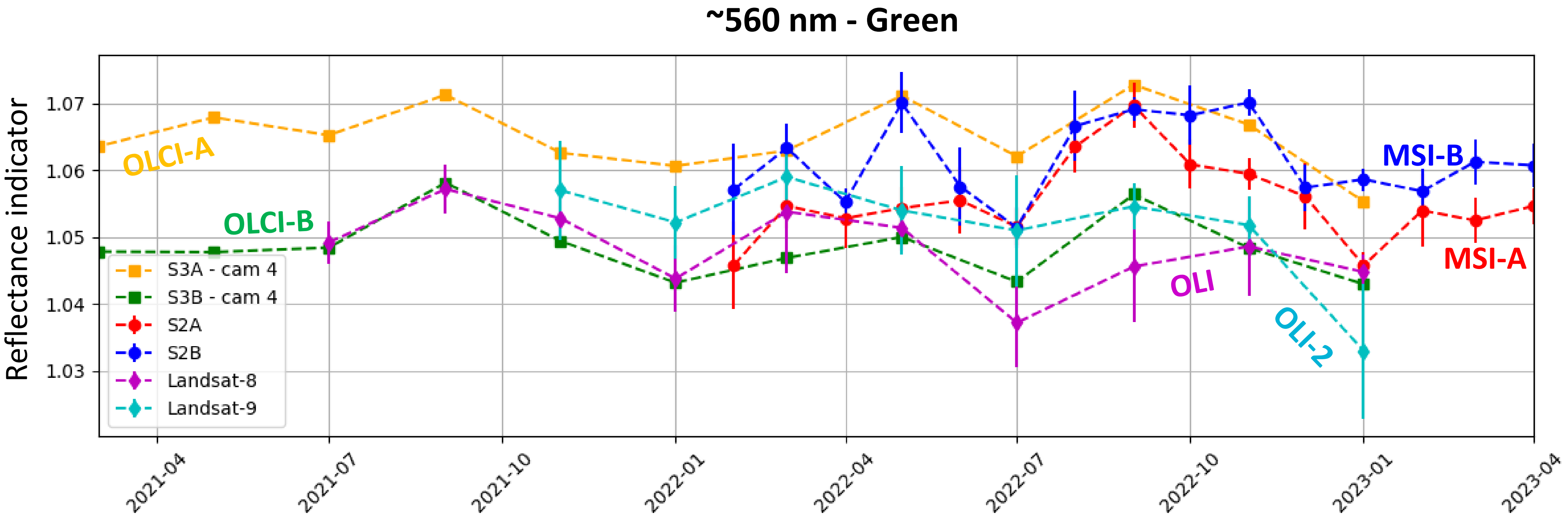
Time-series



- OLCI-A and OLCI-B : 1.5 to 2.5% stable bias
- OLI and OLI-2 ~aligned with OLCI-B
- MSI-A and MSI-B between OLCI-A and OLCI-B
- Overall dispersion of 3% max.

Results

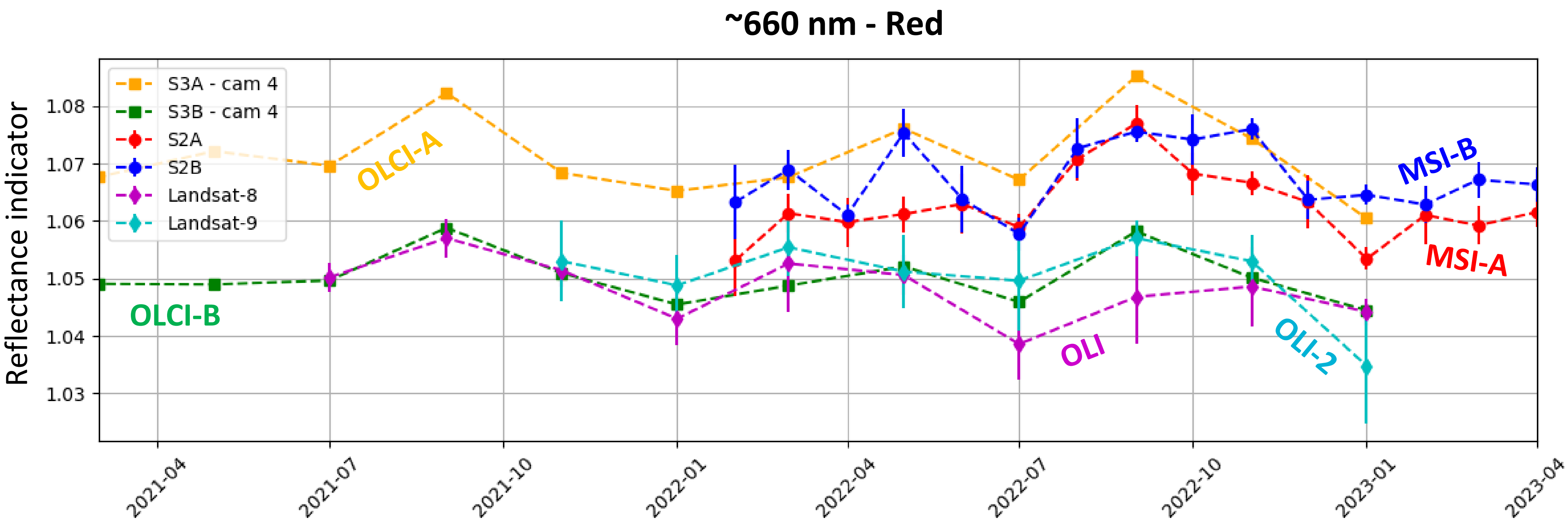
Time-series



- Lower bias between OLCI-A and OLCI-B (1 - 2% max.)
- Lower overall dispersion: 2.5% max. in July and Sept. 2022, January 2023

Results

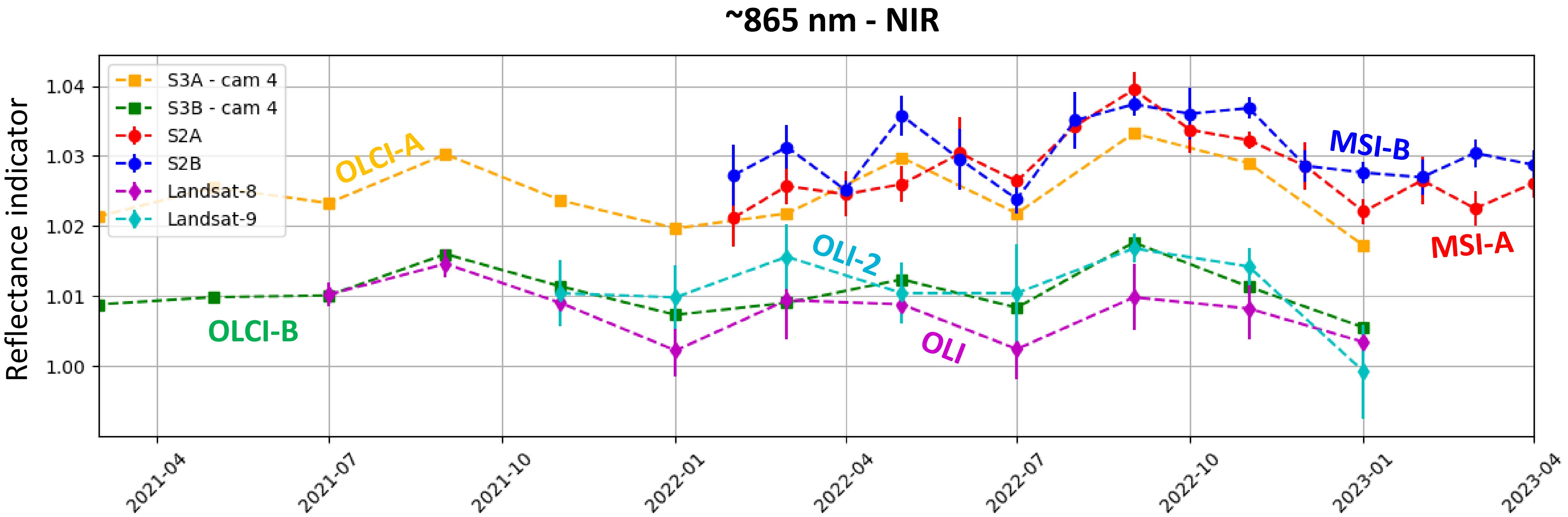
Time-series



- Like green band with higher overall dispersion: 2 to ~4 % max. in Sept. 2022

Results

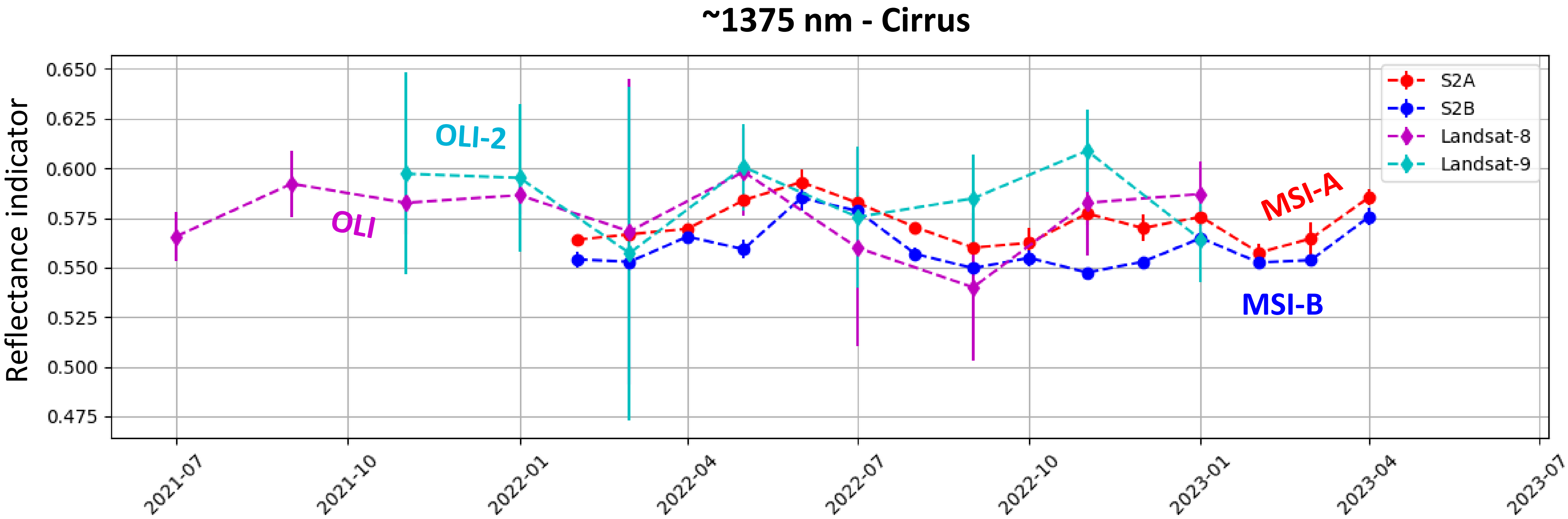
Time-series



- Lower bias between OLCI-A and OLCI-B (1.5% max.)
- Like 443 nm deep blue band:
  - ✓ MSI-A and MSI-B ~aligned with OLCI-A
  - ✓ OLI and OLI-2 ~aligned with OLCI-B

Results

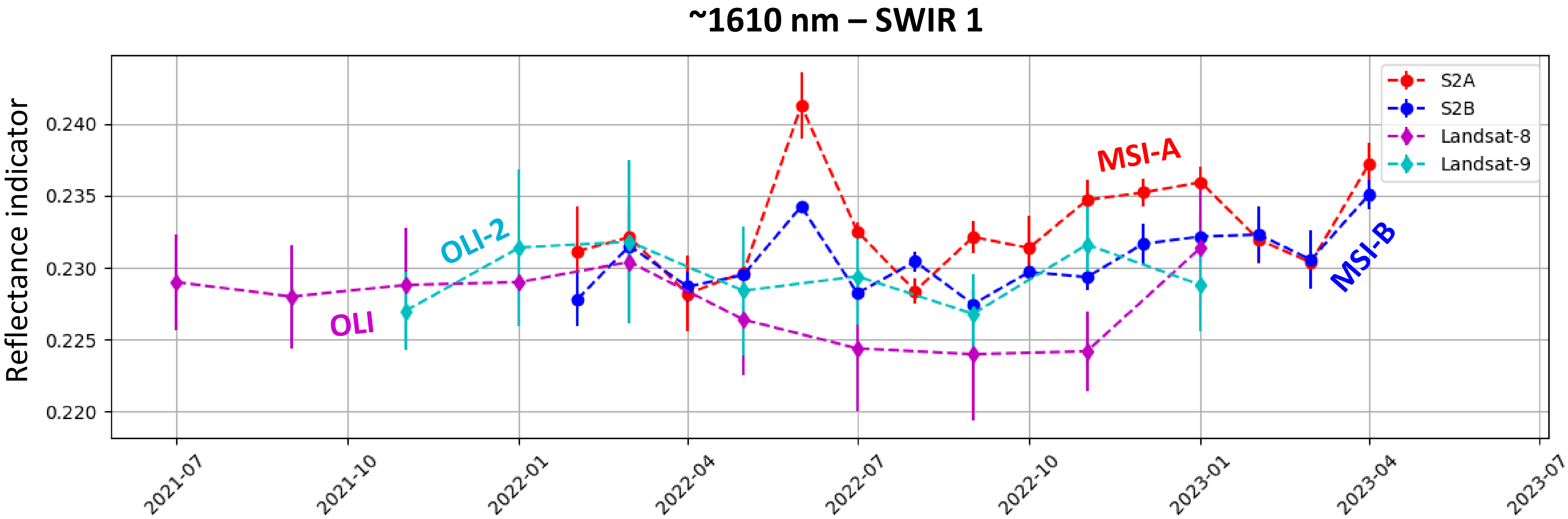
Time-series



- Strong saturation for S2: results are not fully reliable
- Overall dispersion: ~11% max. (Nov. 2022)
- Overall dispersion: < 4% min. (March 2022)

Results

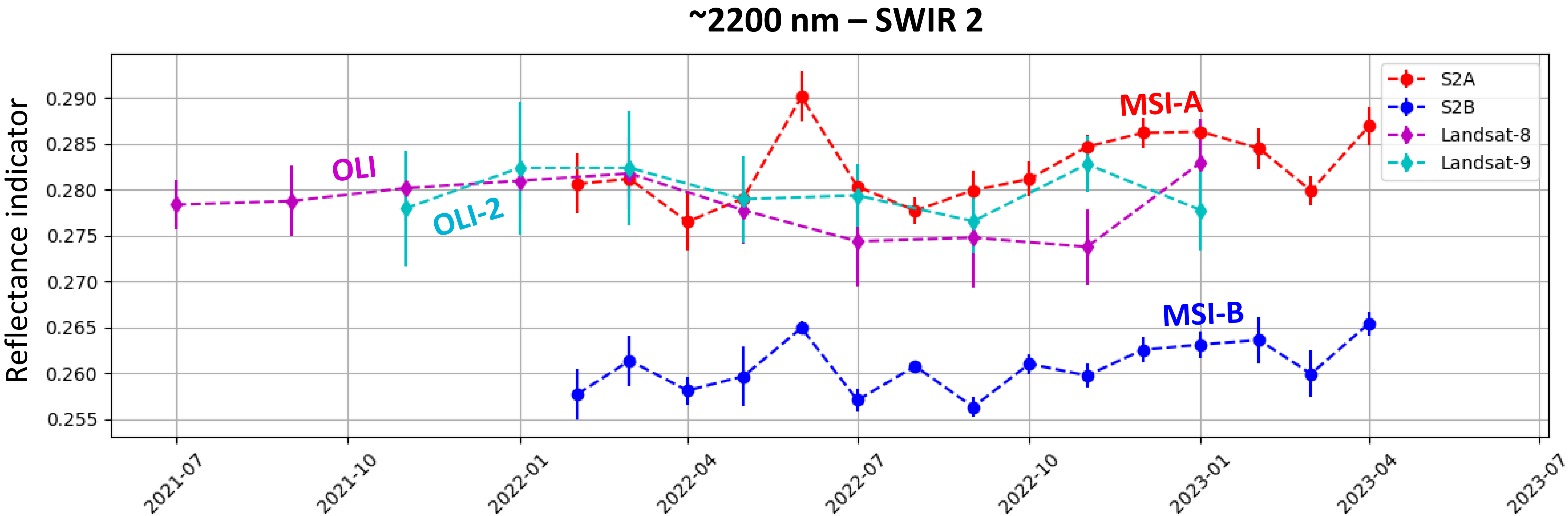
Time-series



- Peak in June 2022 for **MSI-A** and **MSI-B**
- Good alignment of **OLI** / **OLI-2** and **MSI-A** / **MSI-B** early 2022
- Deviation until Nov. 2022, converge again in Jan. 2023

Results

Time-series



- Important bias between **MSI-A** and **MSI-B** (~8%)
- Peak in June 2022 for **MSI-A** (and **MSI-B**)
- **OLI** / **OLI-2** aligned with **MSI-A** early 2022, slight deviation after

Conclusions (so far)

- **In the VNIR:**
  - ✓ Very good agreement between OLCI-A camera 4, MSI A and B on one hand
  - ✓ And Landsat 8-9 and OLCI-B on the other hand
  - ✓ Difference of ~1.5% between the two groups
- **In the SWIR:**
  - ✓ Surprisingly good agreement on cirrus band
  - ✓ All satellites agree very well except S2B B12: unexplained bias
- **Overall:**
  - ✓ No systematic drift for any mission

Perspectives

- Work in progress to be consolidated
- Multi-year time series needed to assess seasonal effects
- Other satellites to be considered: SLSTR, S2C (including tandem phase)
- Analyse BRDF effects (viewing and sun angles)
- Analyse impact of clouds properties and local solar time (e.g. using Meteosat data)
- Uncertainties from spectral response differences and atmospheric correction to be estimated