Deep Convective Clouds for Sentinel-3 OLCI Cross-Calibration Monitoring

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www.calcon.sdl.usu.edu

Sentinel-3 Tandem for Climate Study (S3TC), European Space Agency
Science and Society Contract 4000124211/18/I-EF

Sentinel-3 of the European Space Agency

- **Sentinel-3: measure sea surface topography, sea and land surface temperature, and ocean and land surface colour**
  (https://sentinel.esa.int/web/sentinel/missions/sentinel-3)

- **A series of satellites with same set of instruments**
  - **Sentinel-3A was launched in Feb 2016 with 4 instruments on-board**
  - **Sentinel-3B launch on 25th April 2018 (identical payload)**
  - **It was decided to put S3B in a tandem formation with Sentinel-3A during the commissioning phase, before joining its operational position**

    → see details in the presentation of S. Clerc

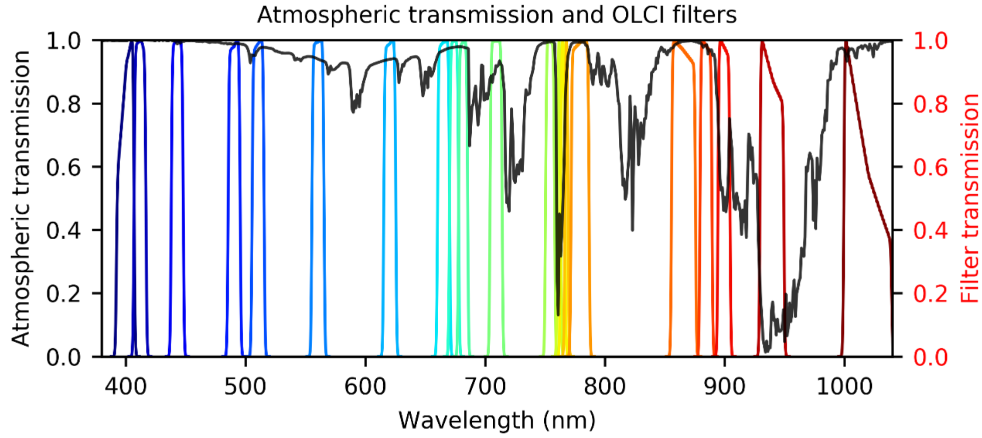
    "New Perspectives for Inter-Calibration using Sentinel-3 Tandem Data"
  - **Sentinel-3C and -3D in preparation, next generation in discussion**

- **Strong interest for long-term monitoring of the calibration of each unit and cross-calibration of the series**
- **Presently assessed for OLCI-A and OLCI-B**

OLCI tandem phase analysis

❖ OLCI: Ocean and Land Colour Instrument

- Push-broom imaging spectrometer
- LEO
- VNIR: 21 bands (400-1020 nm)
- GSD: 300 m at nadir (FR)
- Swath width: 1270 km
- 5 cameras, tilted to avoid glint



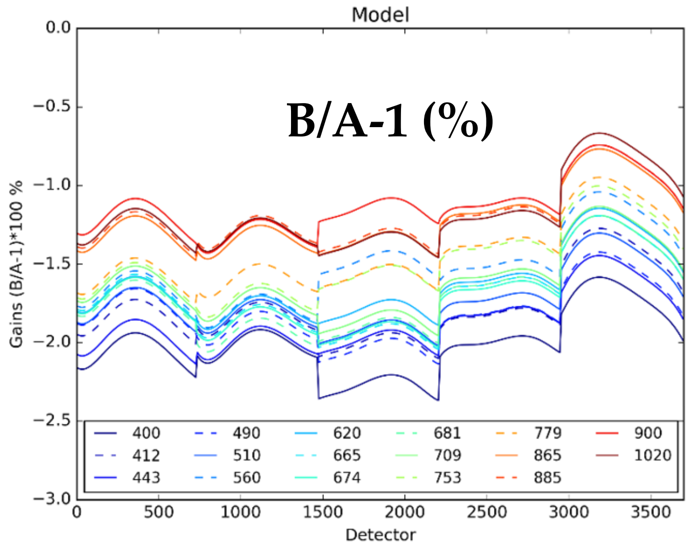
❖ Analysis of the tandem phase

- Adjust the sensors radiometry to slight spectral and geometrical differences (homogenisation)
- Compare the homogenised radiometry for cross-calibration (harmonisation)
- OLCI-A is found brighter than OLCI-B
- About 2% differences in blue to 1% in NIR
- Full details:

Lamquin, N., Clerc, S., Bourg, L., Donlon, C. OLCI A/B Tandem Phase Analysis, Part 1: Level 1 Homogenisation and Harmonisation. Remote Sens. 2020, 12, 1804.

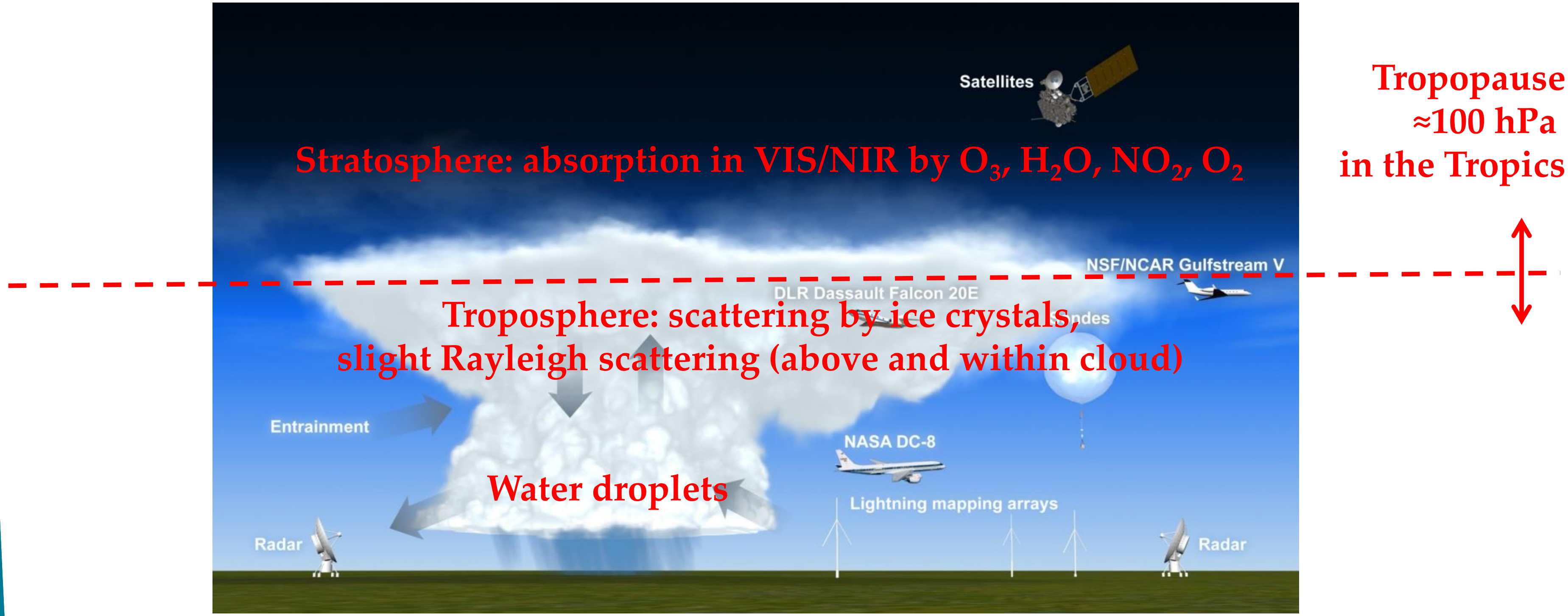
- Benefits at L2:

Lamquin, N.; Déru, A.; Clerc, S.; Bourg, L.; Donlon, C. OLCI A/B Tandem Phase Analysis, Part 2: Benefits of Sensors Harmonisation for Level 2 Products. Remote Sens. 2020, 12, 2702.



Deep Convective Clouds for calibration monitoring

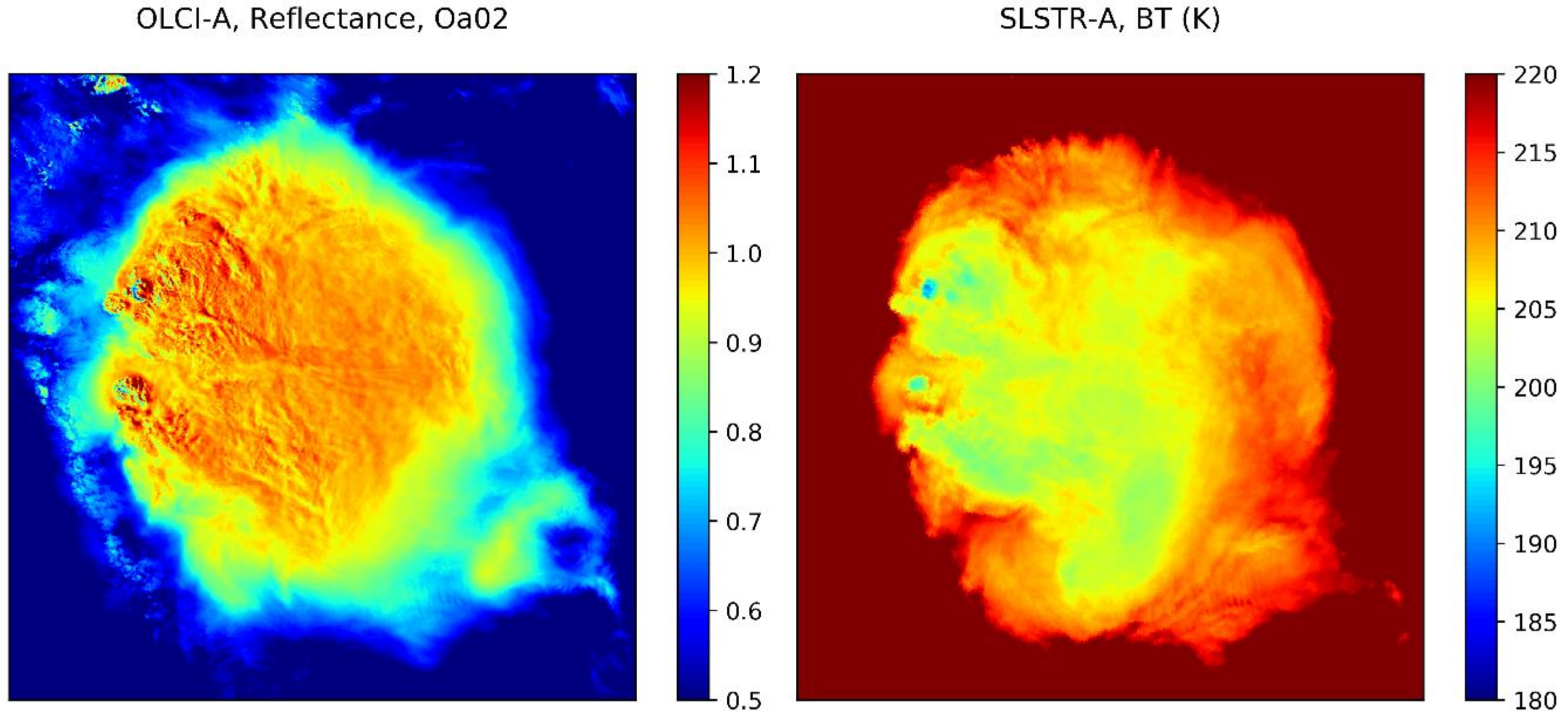
- **History:** DCC targets used for EO sensor calibration since more than two decades (*Vermote and Kaufman, 1995; Hu et al. 2004; Doelling et al. 2004*…)
- **Deep convective clouds (DCC) properties:**
  - ✓ high altitude clouds (close to tropical tropopause), high occurrence in the tropics
  - ✓ bright
  - ✓ white
  - ✓ very vertically-extended (high optical thickness, low/no signature from ground nor boundary layer aerosols from TOA)



https://dc3blog.wordpress.com

Deep Convective Clouds seen by OLCI + SLSTR

- OLCI + SLSTR thermal infrared (10.85 um) channel for Brightness Temperature
- Preselection with BT<225 K (GSICS recommends DCC method using a selection BT<205 K to isolate convection cores)



OLCI reflectance 412 nm

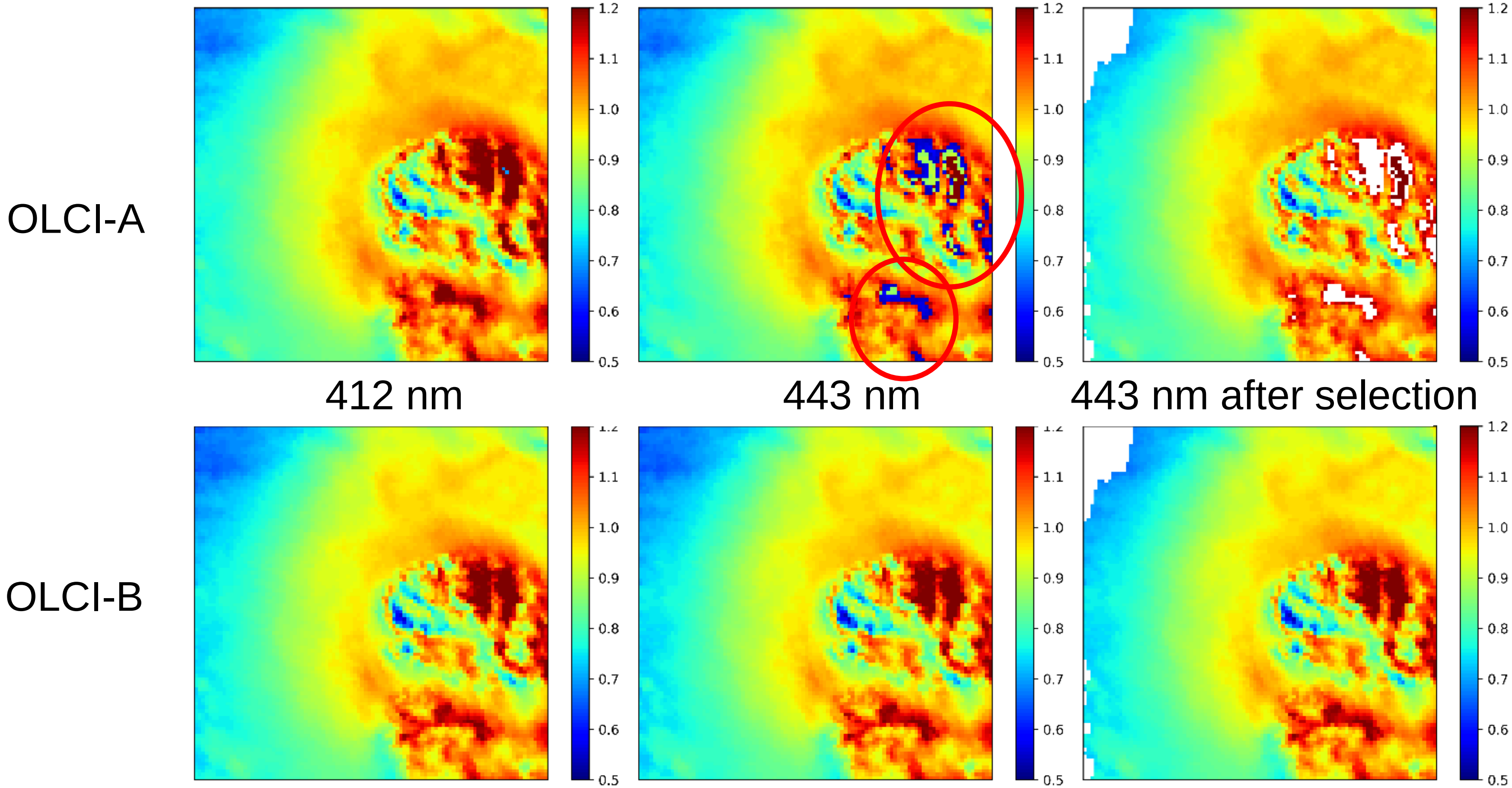
SLSTR Brightness T 10.85 um

- Use of gas-corrected TOA reflectance (i.e. top-of-DCC reflectance)

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

Deep Convective Clouds seen by OLCI: saturation

- OLCI-A saturates much more often than OLCI-B, which traduces in very abnormal values
- Some OLCI-A bands are however “safe” and are considered as “reference” for the reconstruction of the affected bands from interband relationships

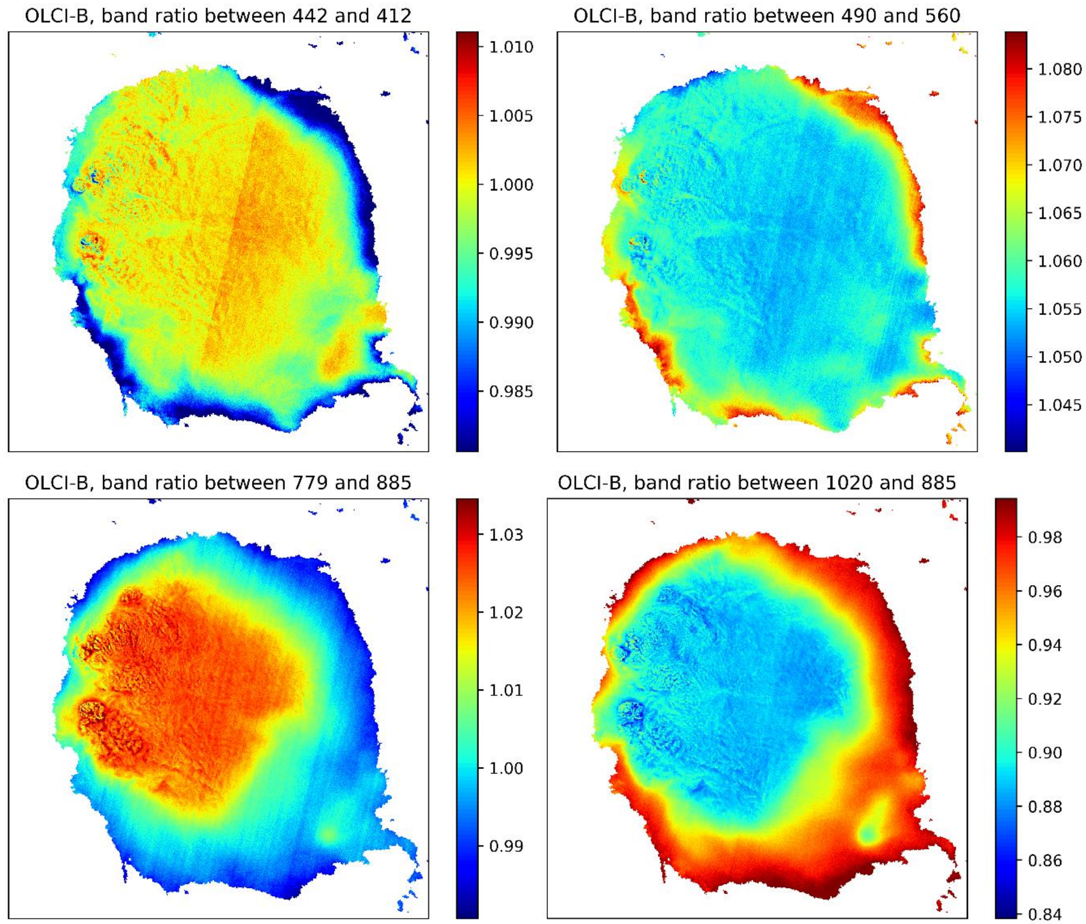


Deep Convective Clouds seen by OLCI: interband

- ❖ **OLCI-A saturates much more often than OLCI-B, which traduces in very abnormal values**
- ❖ **Some OLCI-A bands are however "safe" and are considered as "reference" for the reconstruction of the affected bands from interband relationships**
- ❖ **Variability wrt microphysics and macrophysics**
- ❖ **Higher in NIR than in VIS**

VIS

NIR



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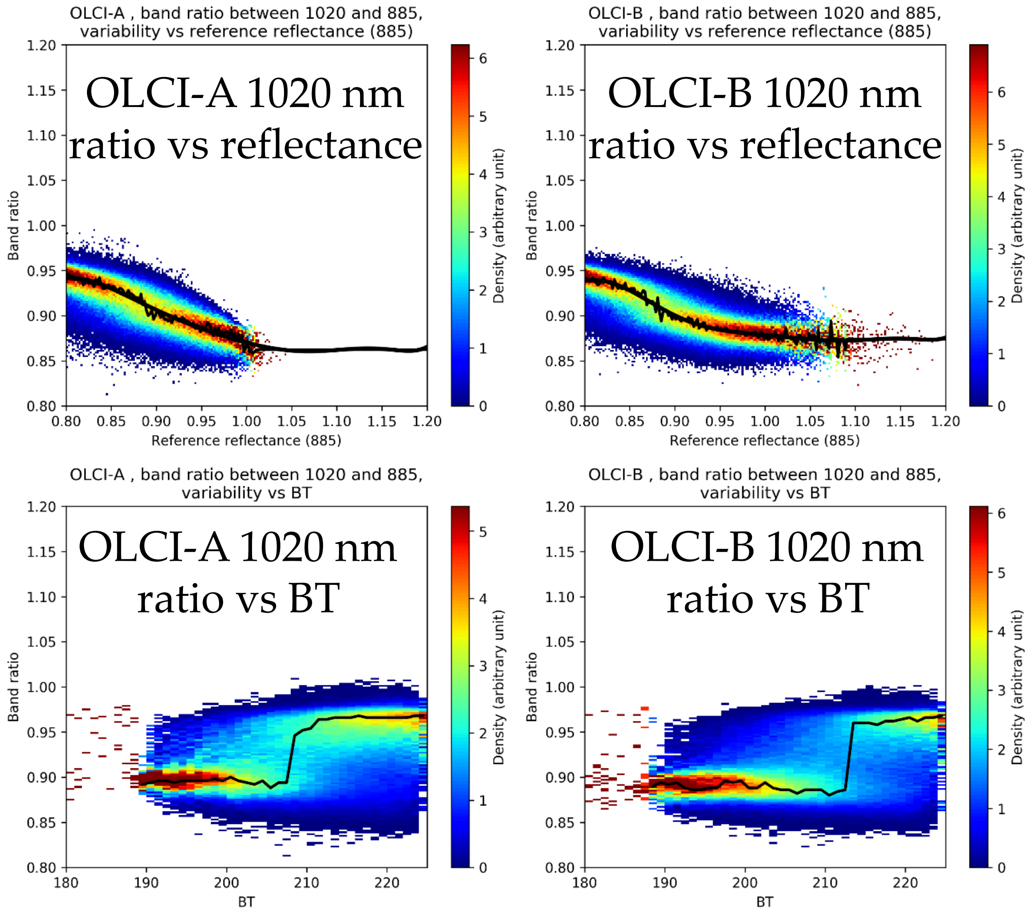
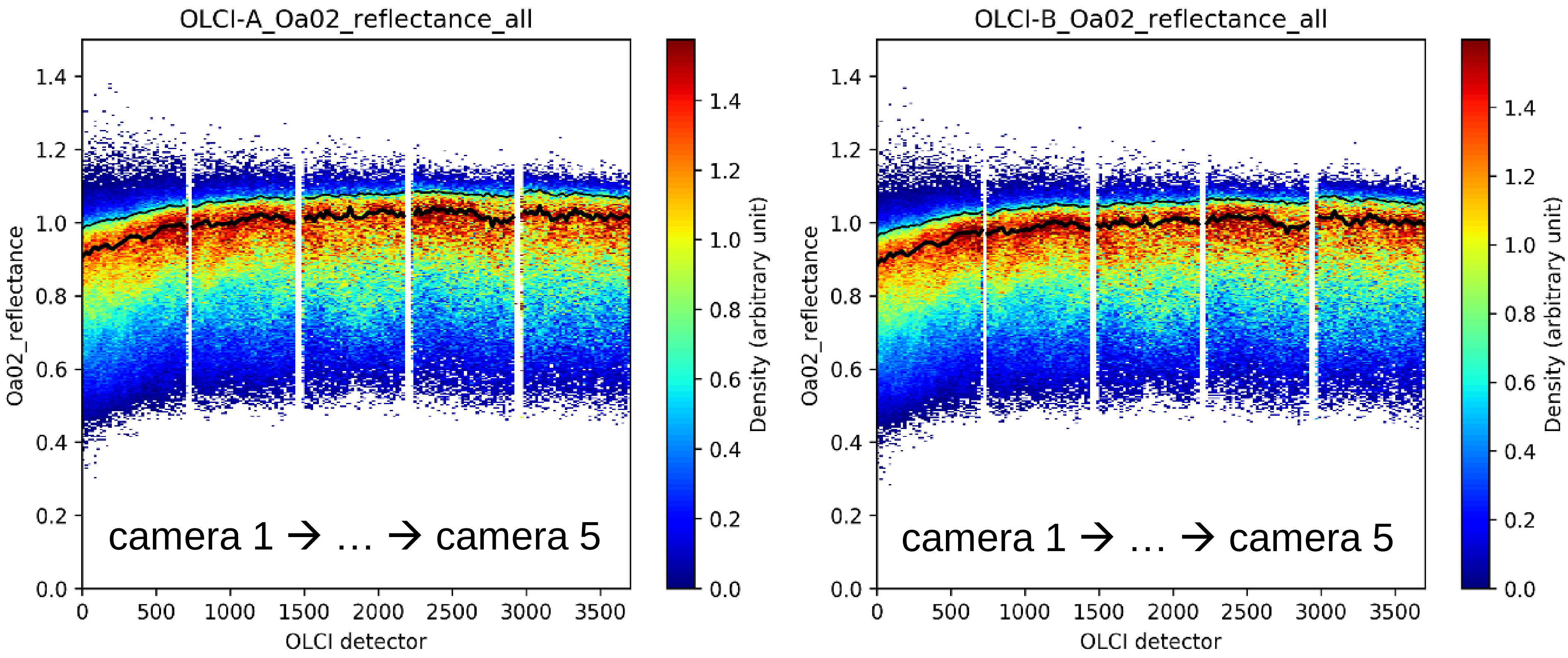


- Smoother relationships found between the interband ratio and the reflectance in the reference channel
- Very similar relationships for OLCI-A and OLCI-B
- OLCI-B relationship used when the one of OLCI-A is uncertain (only 779 and 1020 nm)
  → leads to less precision
- These relationships handle both the natural variability of the relationship and the interband calibration, computed per month of data

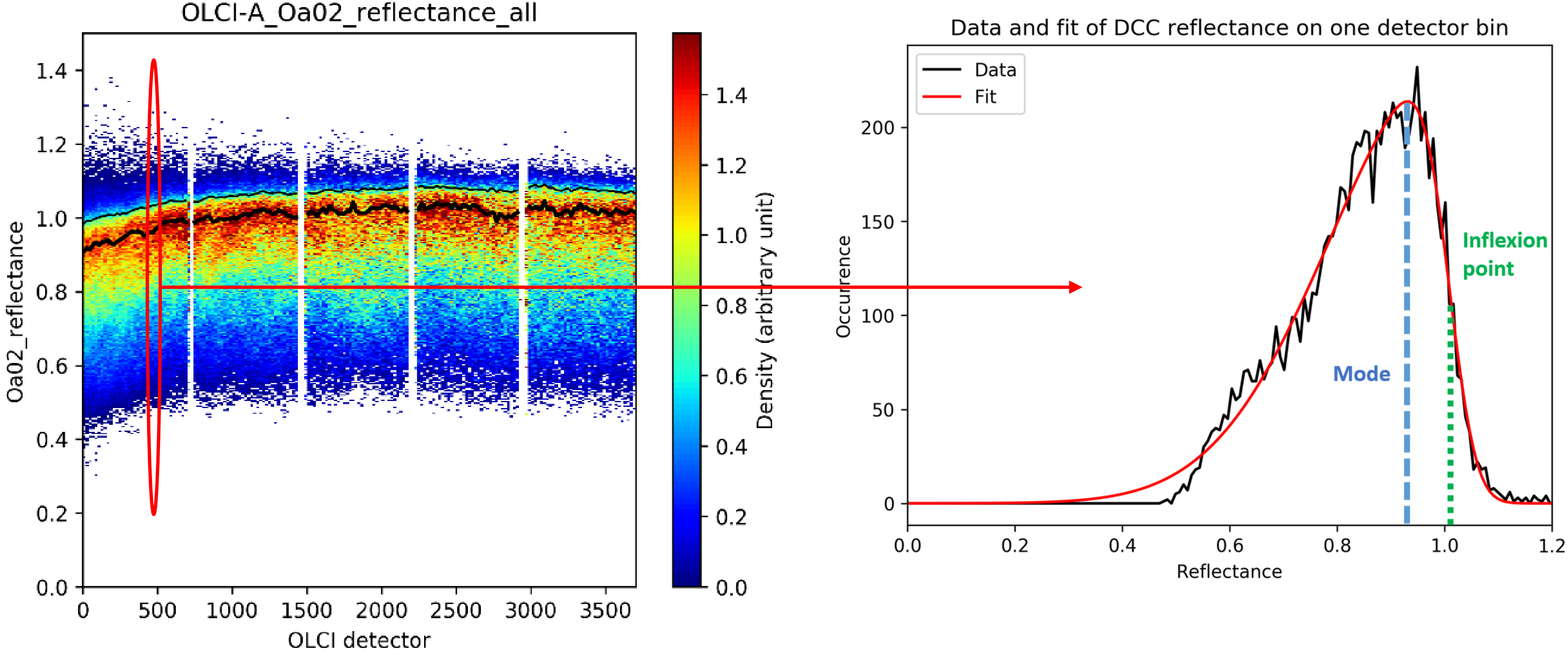
Methodology (1)

- **Collect DCC observations along OLCI FOV**
- **Correct for saturation using interband relationships (mostly for OLCI-A)**
- **Perform statistical analysis per Viewing angle (or OLCI detector)**
- **Example at 412 nm (band « Oa02 »)**

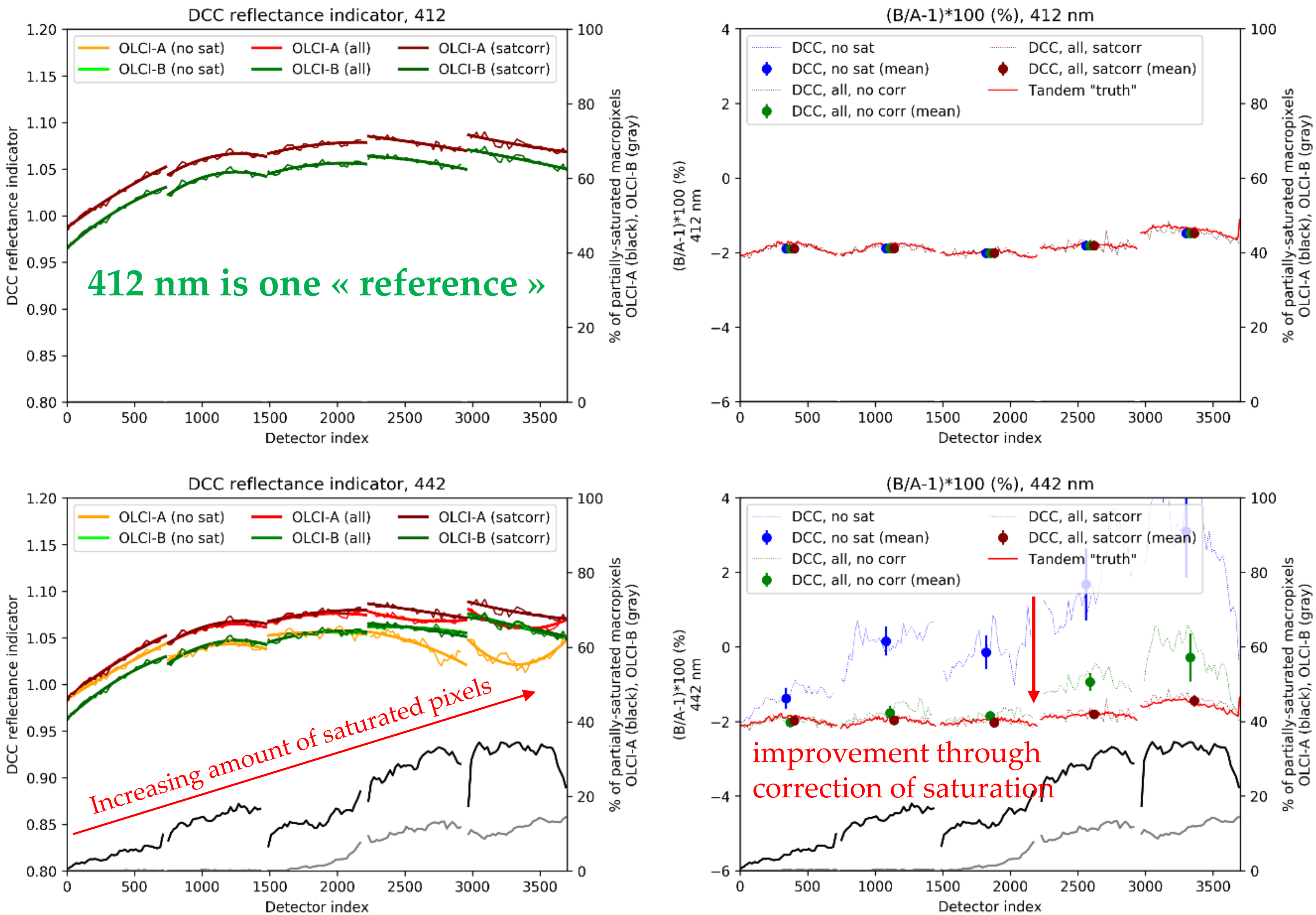


Methodology (2)

- Per OLCI detector bin PDF modeled as skewed-gaussian functions
- Mode and inflexion point of PDF
- Inflexion is found more stable (e.g. through random-draw)



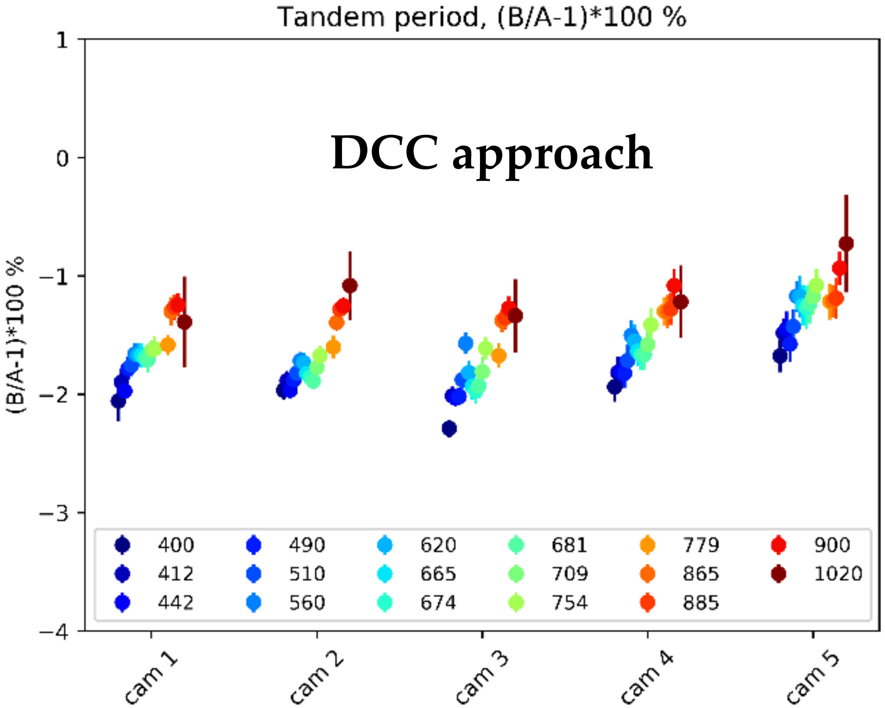
Results (1): comparisons ACT from tandem phase

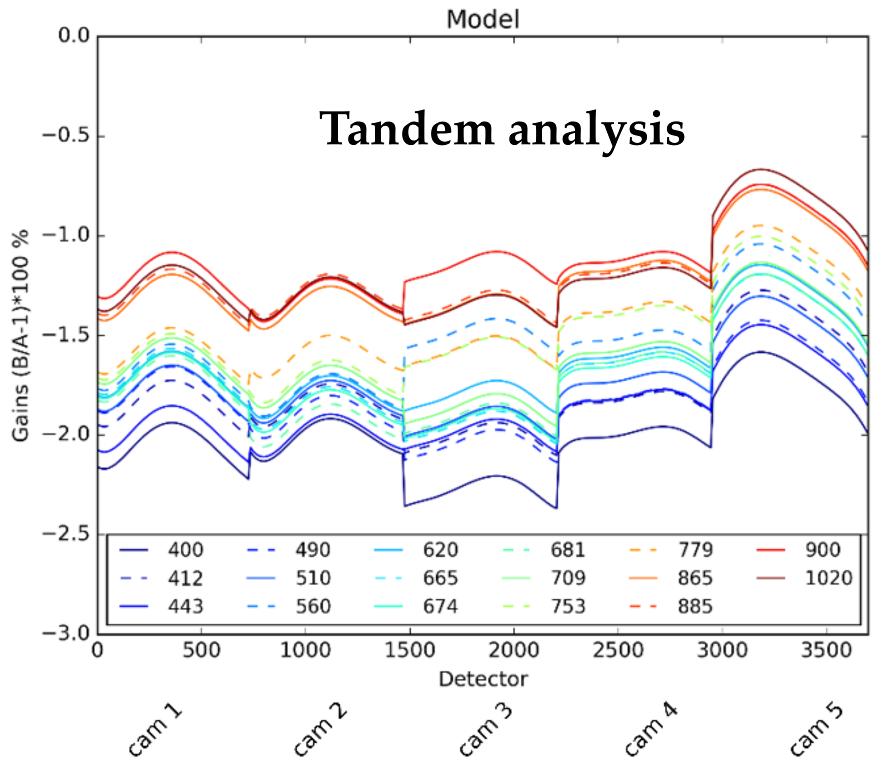


442 nm is affected by saturation

Results (2a): synthesis from tandem phase

- Tandem phase allows to validate the approach
- Comparisons between DCC statistical analysis and tandem colocation analysis agrees very well

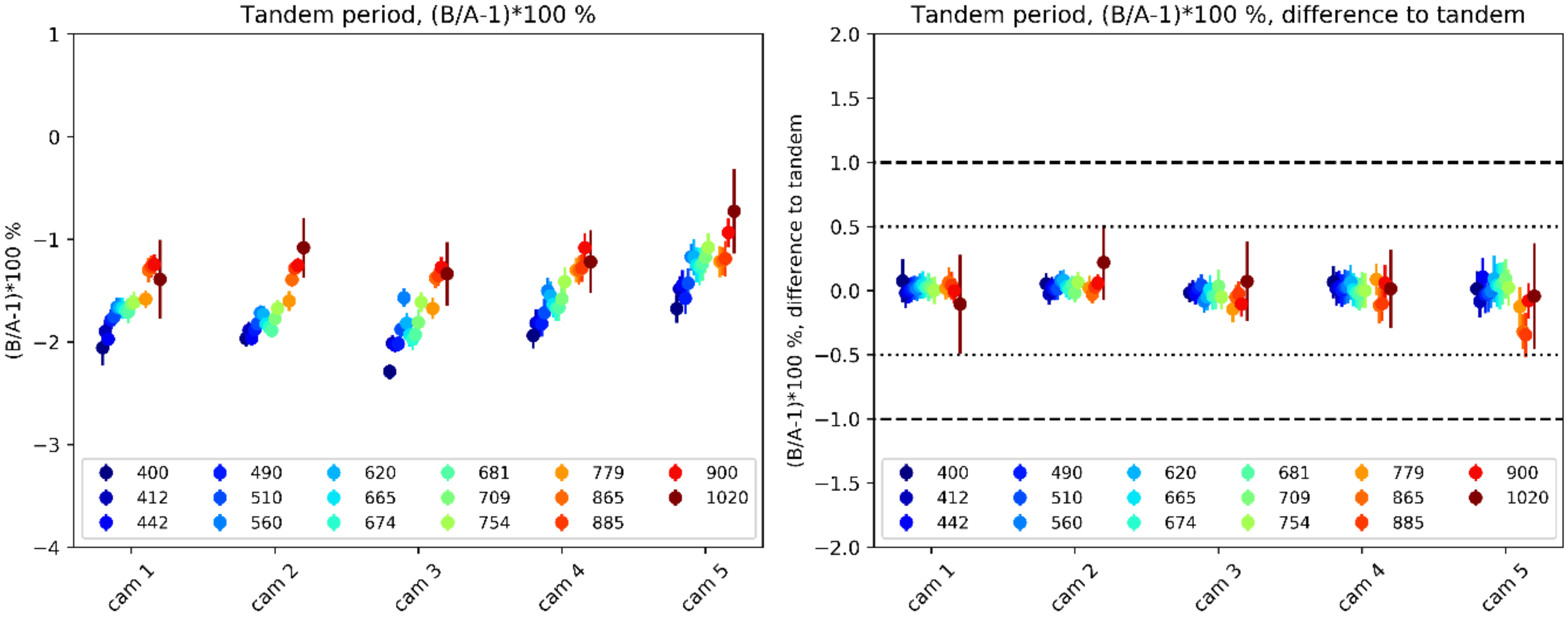




- 1020 nm: less precision due to less precise reconstruction of the saturated observations in OLCI-A

Results (2b): synthesis from tandem phase

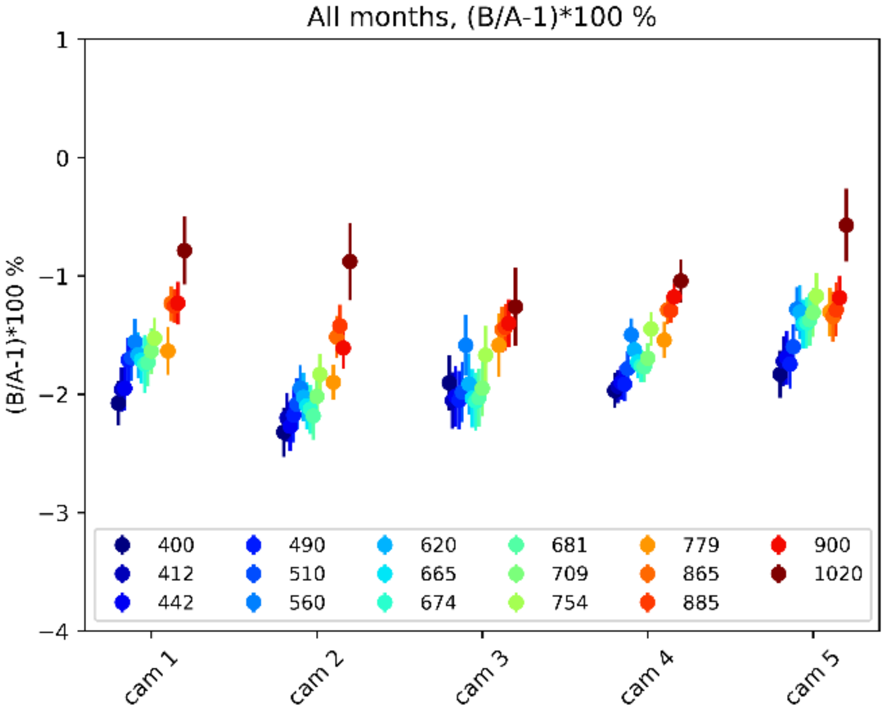
- Tandem phase allows to validate the approach
- Comparisons between DCC statistical analysis and tandem colocation analysis agrees very well

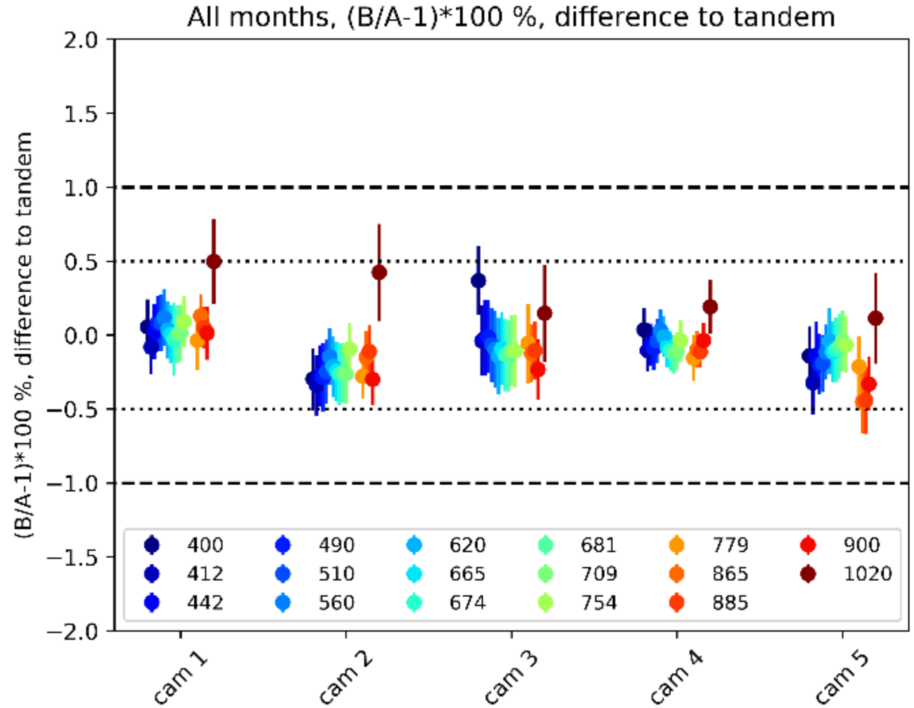


- 1020 nm: less precision due to less precise reconstruction of the saturated observations in OLCI-A

Results (3a): out of tandem phase

- **Similar exercise with operational data, out of tandem (1.5 yr later)**
- **4 months data (Nov 2019, Jan 2020, Mar 2020, Jun 2020)**



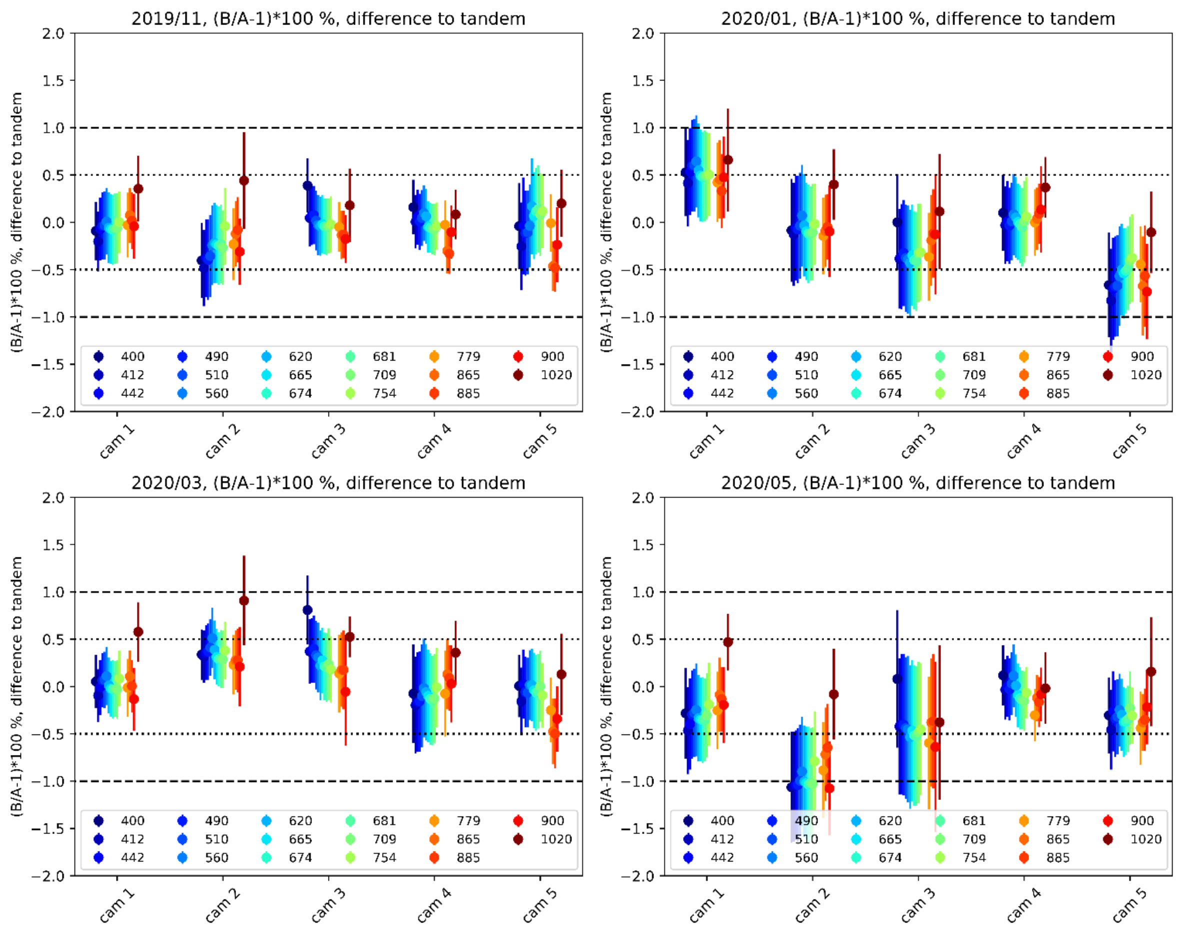


- **Very similar behaviour, except 400 nm (camera 3) and 1020 nm**

  < 0.5 % difference between tandem and post-tandem

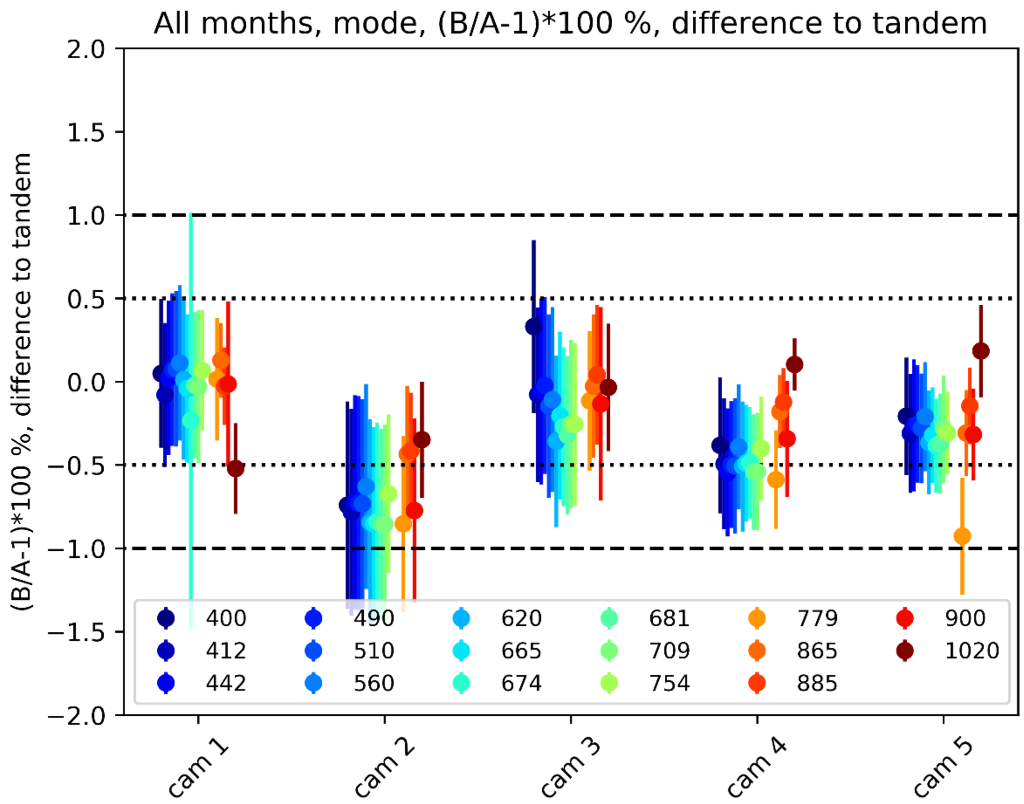
Results (3b): out of tandem phase

- monthly statistics provide more variability
- < 1% overall
- Increasing precision with increasing statistics
- Increasing accuracy with increasing statistics might be due to sampling of geographical variability



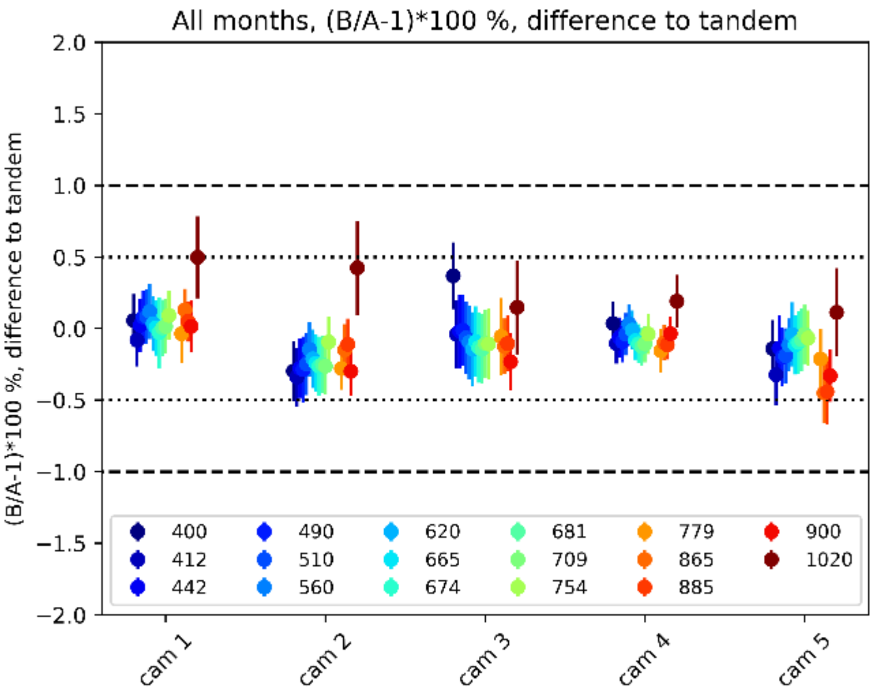
Results (3c): out of tandem phase

❖ **Using the mode instead of the inflexion point in DCC PDFs is less reliable**

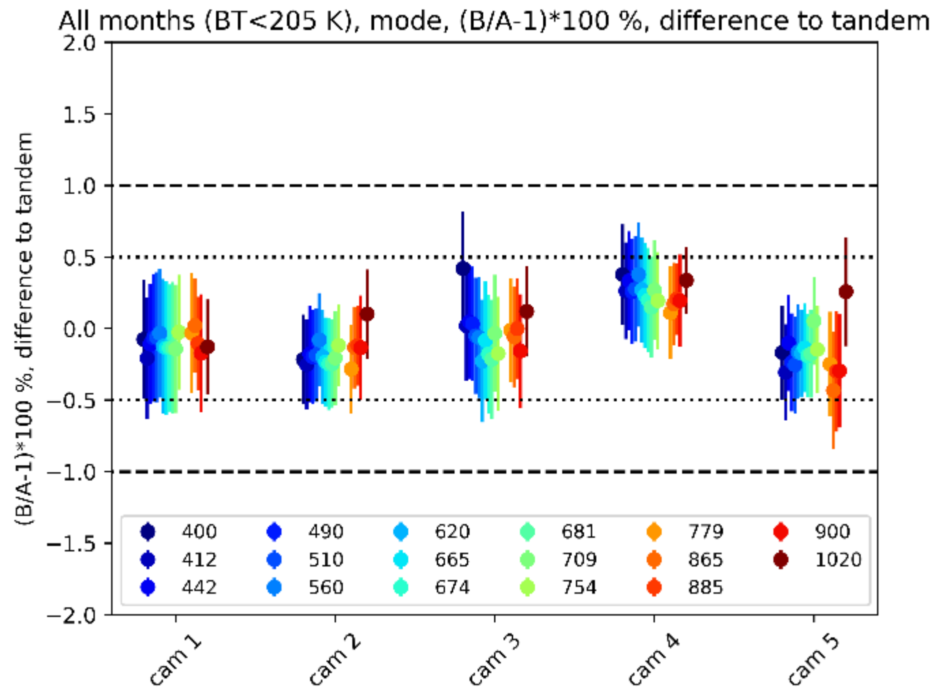


Results (3d): out of tandem phase

- BT<205 K, in combination with using the mode, provides similar results qualitatively, further improvement at 1020 nm (NIR)
- However less precision in the method (more dispersion) due to less samples



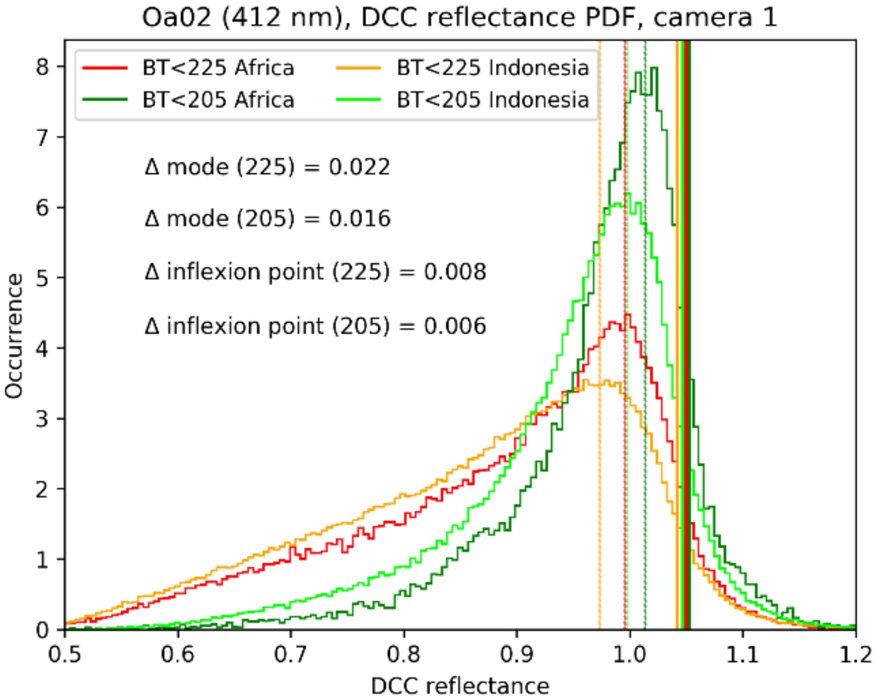
Inflexion point statistics, **BT<225 K**

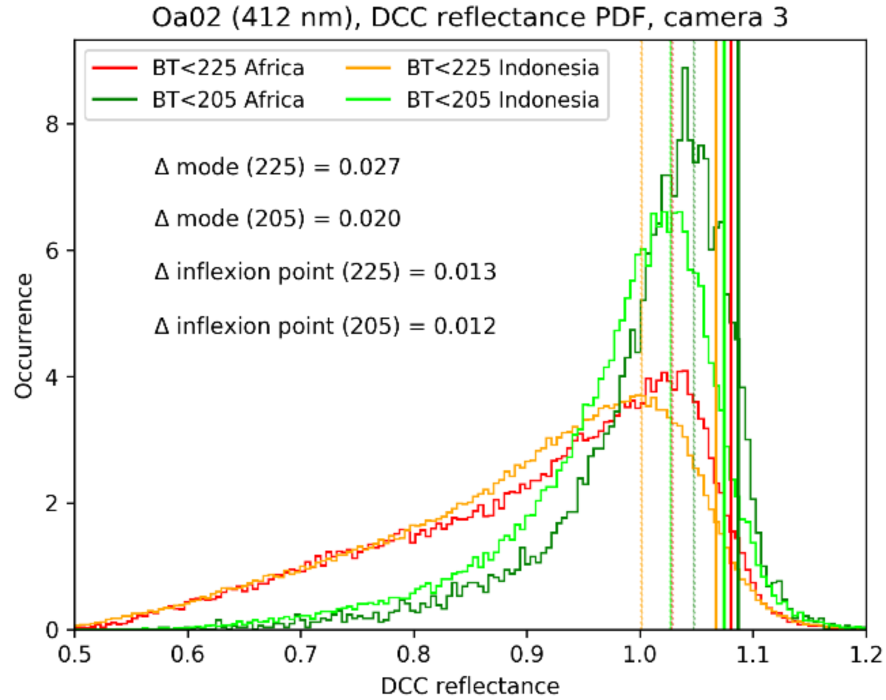


Mode statistics, **BT<205 K**

Results (3e): out of tandem phase

- Differences in PDF wrt BT and geographical regions





- Inflexion point is less sensitive to regional variability and BT threshold
- Slight differences are however in line with the monthly variability in the results

Conclusions and recommendations

- DCCs to be used for long-term monitoring of the OLCI-A and OLCI-B cross-calibration
- Saturation to be corrected for OLCI-A, avoid such problems for next OLCI missions
- The use of the inflexion point of DCCs PDFs provides better precision and accuracy, to the exception of the NIR band at 1020 nm
- Our results provide evidence that the cross-calibration factors found from the tandem phase analysis persist over time, here shown within 0.5%
- We recommend exploiting this methodology further over the OLCI mission to investigate further geographical variabilities, as well for other series of sensors
- Overall this exercise shows the potential of using tandem phase information for developing and assessing new methodologies

- All details in : *Lamquin, N., Bourg, L., Clerc, S., Donlon, C. OLCI A/B Tandem Phase Analysis, Part 3: Post-tandem monitoring of cross-calibration from statistics of Deep Convective Clouds observations. to be published very very soon*