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

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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:
    Benefits at L2:
**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

Stratosphere: absorption in VIS/NIR by $O_3$, $H_2O$, $NO_2$, $O_2$

Tropopause $\approx 100$ hPa in the Tropics

Troposphere: scattering by ice crystals, slight Rayleigh scattering (above and within cloud)

Water droplets
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)

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

OLCI reflectance 412 nm
SLSTR Brightness T 10.85 um

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

[Images of OLCI-A and OLCI-B bands at 412 nm, 443 nm, and 443 nm after selection.]
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
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

- 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

412 nm is one « reference »

442 nm is affected by saturation

Increasing amount of saturated pixels

improvement through correction of 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
  - Δ mode (225) = 0.022
  - Δ mode (205) = 0.016
  - Δ inflexion point (225) = 0.008
  - Δ inflexion point (205) = 0.006

- 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