PREPARATION AND OPERATIONS OF THE MISSION PERFORMANCE CENTRE (MPC) FOR THE COPERNICUS SENTINEL-3 MISSION

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1 Processing Baseline Version

1.1 Sentinel3-A

IPF	IPF / Processing Baseline version	Date of deployment
OL1	06.08 / 2.58	NRT: 29/10/2019 08:26UTC NTC 29/10/2019 08:26UTC
OL2 LAND	06.13 / 2.60	NRT: 27/11/2019 09:38 UTC NTC: 27/11/2019 09:38 UTC
OL2 MAR	06.12 / 2.38	NRT: 29/08/2018 09:24 UTC NTC: 29/08/2018 09:33 UTC
SY2	06.17 / 2.51	NTC: 30/05/2019 11:00 UTC
SY2_VGS	06.07 / 2.44	NTC: 21/01/2019 10:06 UTC

1.2 Sentinel3-B

IPF	IPF / Processing Baseline version	Date of deployment
OL1	06.08 / 1.30	NRT: 29/10/2019 08:26 UTC NTC: 29/10/2019 08:26 UTC
OL2 LAND	06.13 / 1.32	NRT: 27/11/2019 09:38 UTC NTC: 27/11/2019 09:38 UTC
OL2 MAR	06.12 / 1.09	NRT: 29/08/2018 09:24 UTC NTC: 29/08/2018 09:33 UTC
SY2	06.17 / 1.23	NTC: 30/05/2019 11:00 UTC
SY2_VGS	06.07 / 1.16	NTC: 21/01/2019 10:06 UTC

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2 Instrument monitoring

2.1 CCD temperatures

2.1.1 OLCI-A

The monitoring of the CCD temperatures is based on MPMF data extractions not yet operational. In the meantime, we monitor the CCD temperatures on the long-term using Radiometric Calibration Annotations (see Figure 1). Variations are very small (0.09 C peak-to-peak) and no trend can be identified. Data from current cycle (rightmost data points) do not show any specificity.

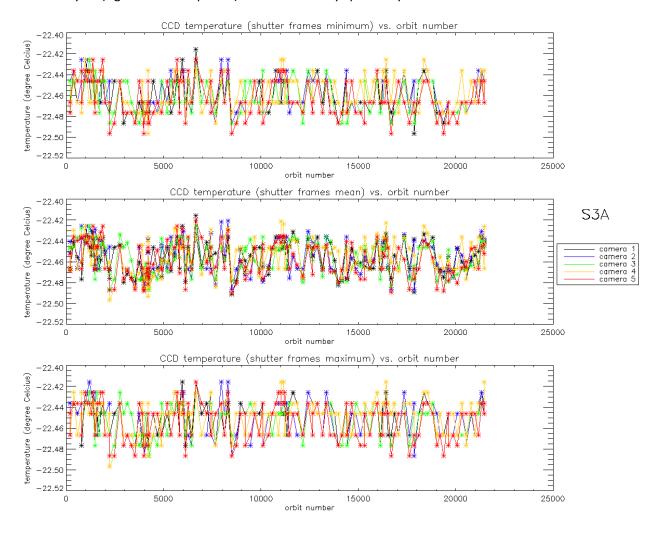


Figure 1: long term monitoring of OLCI-A CCD temperatures using minimum value (top), time averaged values (middle), and maximum value (bottom) provided in the annotations of the Radiometric Calibration Level 1 products, for the Shutter frames, all radiometric calibrations so far except the first one (absolute orbit 183) for which the instrument was not yet thermally stable.

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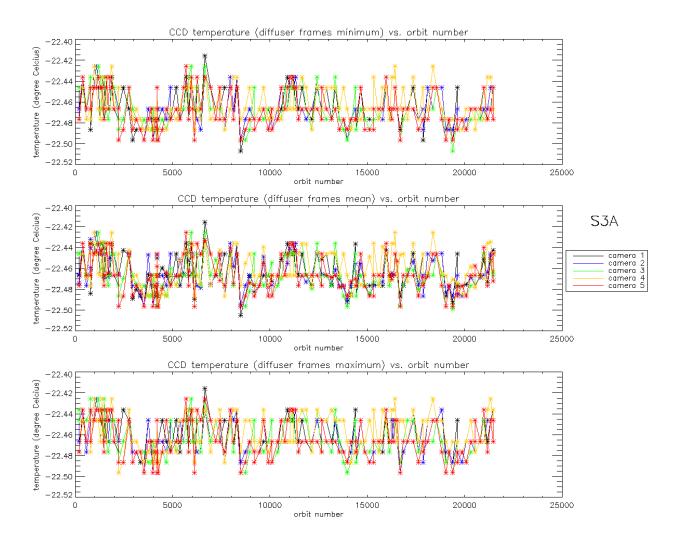


Figure 2: Same as Figure 1 for diffuser frames.

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2.1.2 OLCI-B

As for OLCI-A, the variations of CCD temperature are very small (0.08 C peak-to-peak) and no trend can be identified. Data from current cycle (rightmost data points) do not show any specificity.

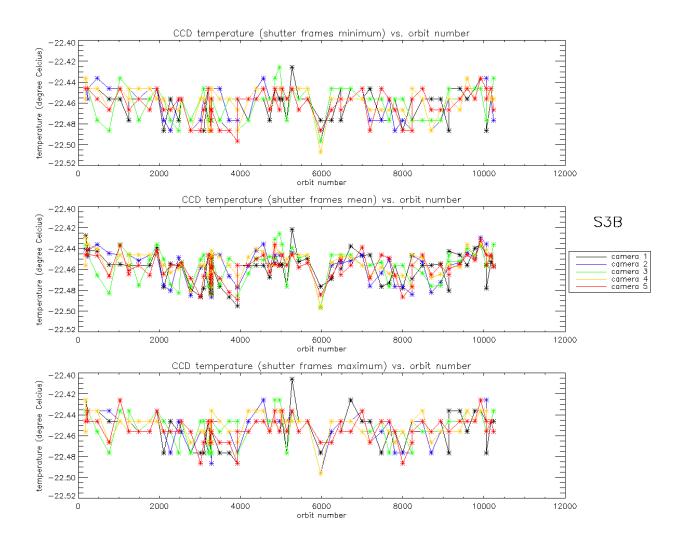


Figure 3: long term monitoring of OLCI-B CCD temperatures using minimum value (top), time averaged values (middle), and maximum value (bottom) provided in the annotations of the Radiometric Calibration Level 1 products, for the Shutter frames, all radiometric calibrations so far except the first one (absolute orbit 167) for which the instrument was not yet thermally stable.

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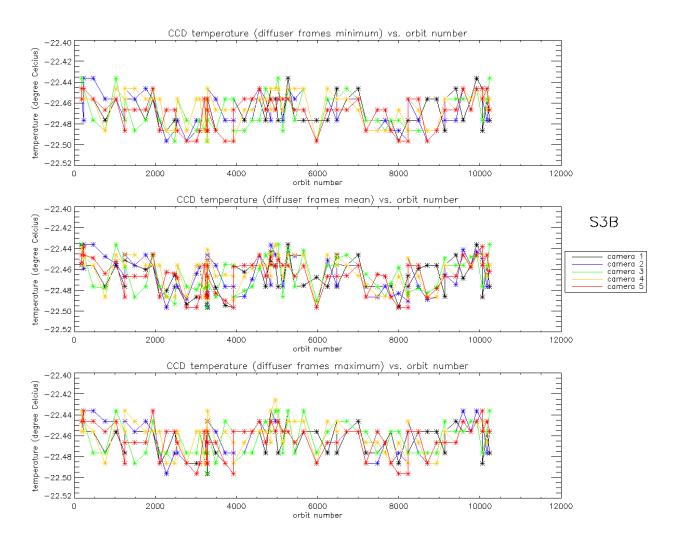


Figure 4: same as Figure 3 for diffuser frames.



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2.2 Radiometric Calibration

For OLCI-A, four Radiometric Calibration Sequences have been acquired during Cycle 056:

- S01 sequence (diffuser 1) on 11/03/2020 18:56 to 18:58 (absolute orbit 21175)
- S01 sequence (diffuser 1) on 22/03/2020 02:19 to 02:21 (absolute orbit 21322)
- S01 sequence (diffuser 1) on 31/03/2020 05:07 to 05:09 (absolute orbit 21452)
- S05 sequence (diffuser 2) on 31/03/2020 06:48 to 06:50 (absolute orbit 21453)

For OLCI-B, five Radiometric Calibration Sequences have been acquired during Cycle 037:

- So1 sequence (diffuser 1) on 21/03/2020 17:15 to 17:17 (absolute orbit 9923)
- S01 sequence (diffuser 1) on 31/03/2020 01:05 to 01:07 (absolute orbit 10056)
- S05 sequence (diffuser 2) on 31/03/2020 02:46 to 02:48 (absolute orbit 10057)
- S01 sequence (diffuser 1) on 08/04/2020 06:00 to 06:02 (absolute orbit 10173)
- S01 sequence (diffuser 1) on 12/04/2020 16:01 to 16:03 (absolute orbit 10236)

The acquired Sun azimuth angles are presented on Figure 5 for OLCI-A and Figure 6 for OLCI-B, on top of the nominal values without Yaw Manoeuvre (i.e. with nominal Yaw Steering control of the satellite).

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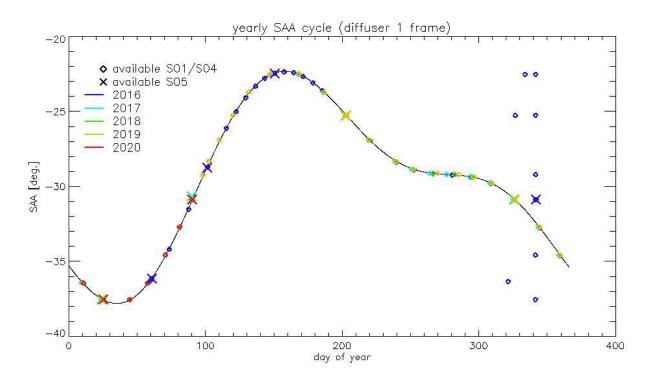


Figure 5: Sun azimuth angles during acquired OLCI-A Radiometric Calibrations (diffuser frame) on top of nominal yearly cycle (black curve). Diffuser 1 with diamonds, diffuser 2 with crosses, 2016 acquisitions in dark blue, 2017 in clear blue, 2018 in green, 2019 in yellow and 2020 in red.

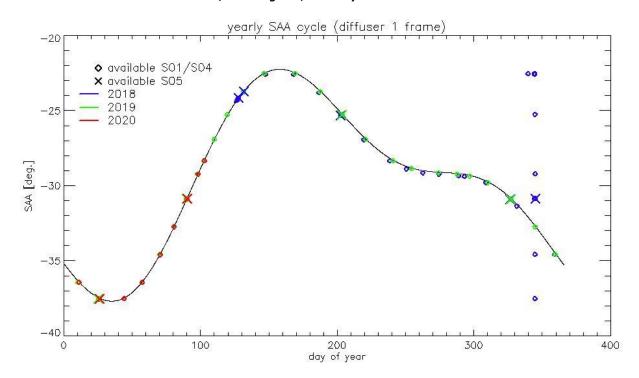


Figure 6: same as Figure 5 for OLCI-B (2018 in blue, 2019 in green and 2020 in red).



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Sun Azimuth Angles as a function of solar zenith Angles are presented in Figure 7 for OLCI-A and Figure 8 for OLCI-B.

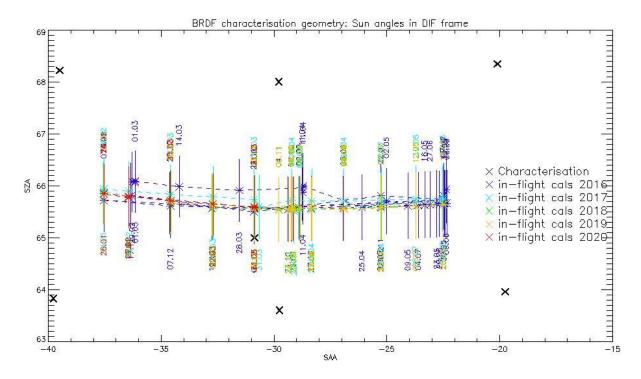


Figure 7: OLCI-A Sun geometry during radiometric Calibrations on top of characterization ones (diffuser frame)

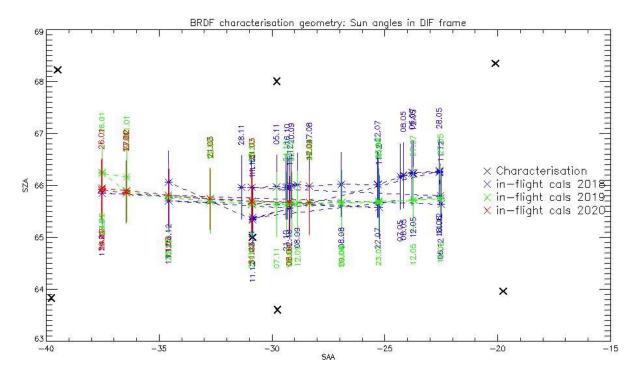


Figure 8: same as Figure 7 for OLCI-B

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2.2.1 Dark Offsets [OLCI-L1B-CV-230]

Note about the High Energy Particles:

The filtering of High Energy Particle (HEP) events from radiometric calibration data has been implemented (for shutter frames only) in a post processor, allowing generating Dark Offset and Dark Current tables computed on filtered data. The post-processor starts from IPF intermediate data (corrected counts), applies the HEP detection and filtering and finally computes the Dark Offset and Dark Current tables the same way as IPF. An example of the impact of HEP filtering is given in Figure 9.

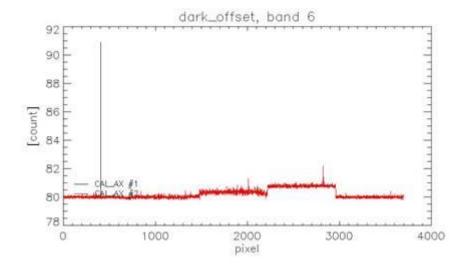


Figure 9: Dark Offset table for band Oa06 with (red) and without (black) HEP filtering (Radiometric Calibration of 22 July 2017). The strong HEP event near pixel 400 has been detected and removed by the HEP filtering.

All results presented below in this section have been obtained using the HEP filtered Dark Offset and Dark Current tables.

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2.2.1.2 OLCI-A

Dark offsets

Dark offsets are continuously affected by the global offset induced by the Periodic Noise on the OCL convergence. Current Cycle calibrations are affected the same way as others. The amplitude of the shift varies with band and camera from virtually nothing (e.g. camera 2, band 0a1) to up to 5 counts (Oa21, camera 3). The Periodic Noise itself comes on top of the global shift with its known signature: high frequency oscillations with a rapid damp. This effect remains more or less stable with time in terms of amplitude, frequency and decay length, but its phase varies with time, introducing the global offset mentioned above.

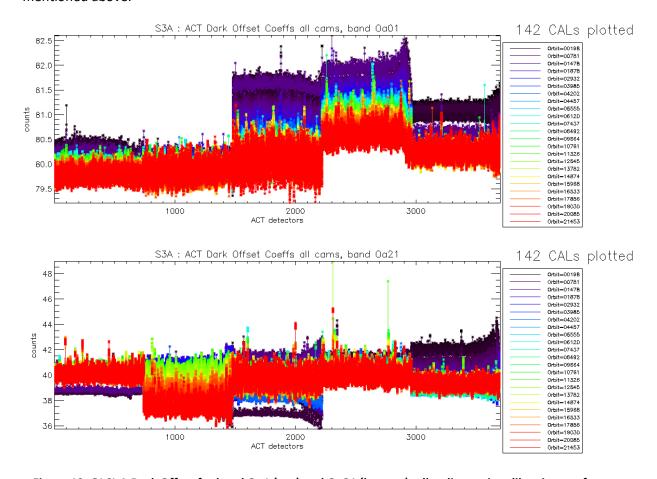


Figure 10: OLCI-A Dark Offset for band Oa1 (top) and Oa21 (bottom), all radiometric calibrations so far except the first one (orbit 183) for which the instrument was not thermally stable yet.

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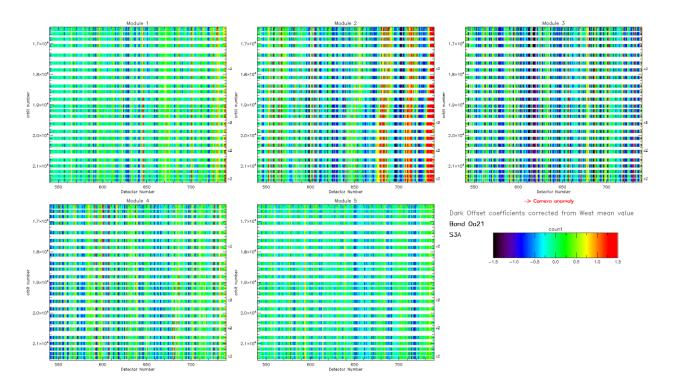


Figure 11: map of OLCI-A periodic noise for the 5 cameras, for band Oa21. X-axis is detector number (East part, from 540 to 740, where the periodic noise occurs), Y-axis is the orbit number. Y-axis range is focused on the most recent 5000 orbits. The counts have been corrected from the West detectors mean value (not affected by periodic noise) in order to remove mean level gaps and consequently to have a better visualisation of the long term evolution of the periodic noise structure. At the beginning of the mission the periodic noise for band Oa21 had strong amplitude in camera 2, 3 and 5 compared to camera 1 and 4. However PN evolved through the



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mission and these discrepancies between cameras have been reduced. At the time of this Cyclic Report Camera 2 still shows a slightly higher PN than other cameras.

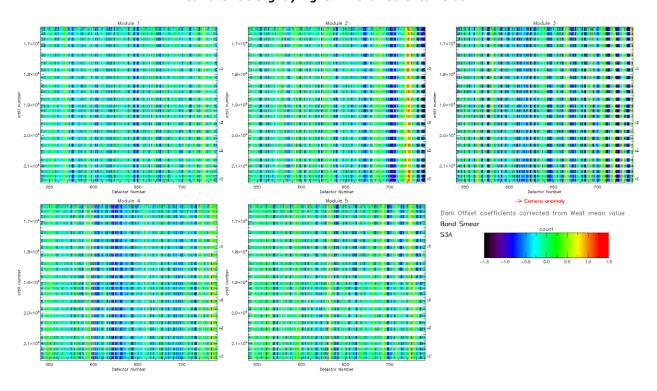


Figure 12: same as Figure 11 for smear band.

Figure 11 and Figure 12 show the so-called 'map of periodic noise' in the 5 cameras, for respectively band 21 and smear band. These maps have been computed from the dark offsets after removal of the mean level of the WEST detectors (not impacted by PN) in order to remove mean level gaps from one CAL to the other and consequently to highlight the shape of the PN. Maps are focused on the last 200 EAST detectors where PN occurs and on a time range covering only the last 5000 orbits in order to better visualize the CALs of the current cycle.

As there was no camera anomaly during the current cycle, there is no sudden change of periodic noise to report during the current cycle. The very small drift of the PN phase which is present since about orbit 18000 in camera 2 Oa21 for the 100 eastern pixels (see Figure 11) seems to be stabilizing. This kind of drift had already been encountered for the same camera/band between orbit 13500 and 14500.

Dark Currents

Dark Currents (Figure 13) are not affected by the global offset of the Dark Offsets, thanks to the clamping to the average blind pixels value. However, the oscillations of Periodic Noise remain visible. There is no significant evolution of this parameter during the current cycle except the small regular increase (almost linear), for all detectors, since the beginning of the mission (see Figure 14).

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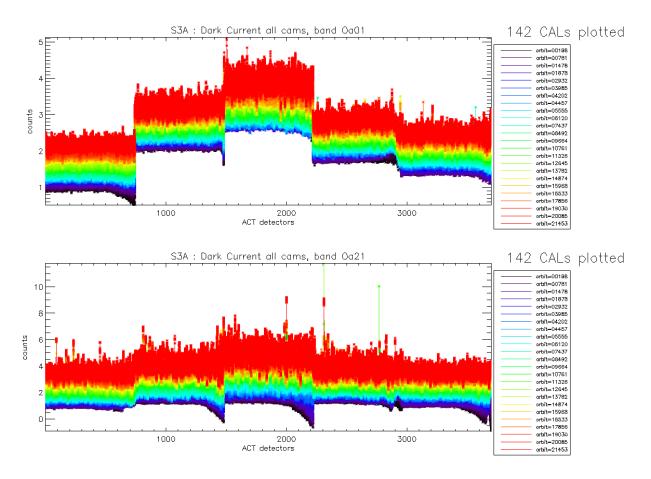


Figure 13: OLCI-A Dark Current for band Oa1 (top) and Oa21 (bottom), all radiometric calibrations so far except the first one (orbit 183) for which the instrument was not thermally stable yet.

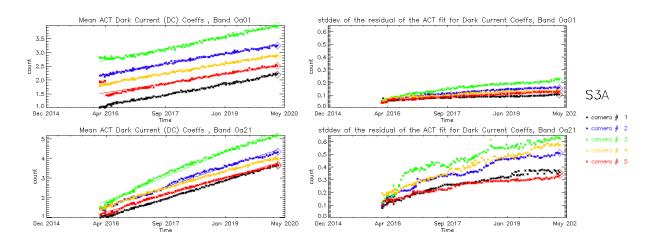


Figure 14: left column: ACT mean on 400 first detectors of OLCI-A Dark Current coefficients for spectral band Oa01 (top) and Oa21 (bottom). Right column: same as left column but for Standard deviation instead of mean.

We see an increase of the DC level as a function of time especially for band Oa21.



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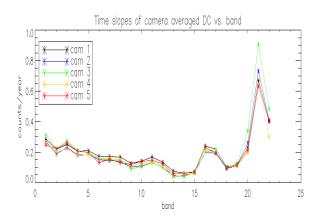
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A possible explanation of the regular increase of DC could be the increase of the number of hot pixels which is more important in Oa21 because this band is made of more CCD lines than band Oa01 and thus receives more cosmic rays impacts. It is known that cosmic rays degrade the structure of the CCD, generating more and more hot pixels at long term scales. Indeed, when computing the time slopes of the spatially averaged Dark Current as a function of band, i.e. the slopes of curves in left plots of Figure 14, one can see that Oa21 is by far the most affected, followed by the smear band (Figure 15, left); when plotting these slopes against total band width (in CCD rows, regardless of the number of micro-bands), the correlation between the slope values and the width becomes clear (Figure 15, right).



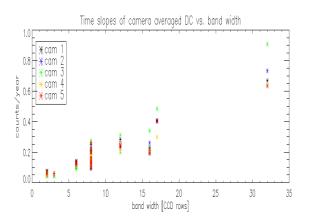


Figure 15: OLCI-A Dark current increase rates with time (in counts per year) vs. band (left) and vs. band width (right)

2.2.1.3 OLCI-B

Dark Offsets

Dark offsets for OLCI-B show a similar behaviour than for OLCI-A: mean level gaps between different orbits, induced by the presence of a pseudo periodic noise on the east edge of the cameras with a drifting phase.

Evolution of OLCI-B Dark Offset coefficients for band Oa01 and Oa21 are represented in Figure 16.

The periodic noise maps are shown for band Oa21 and smear band respectively in Figure 17 and Figure 18. As it happened for OLCI-A after a few thousands of orbits, the strong periodic noise phase and amplitude drift, present at the very beginning of the mission is now showing a clear stabilization.

There is no specific behaviour of the PN to report in the current cycle.

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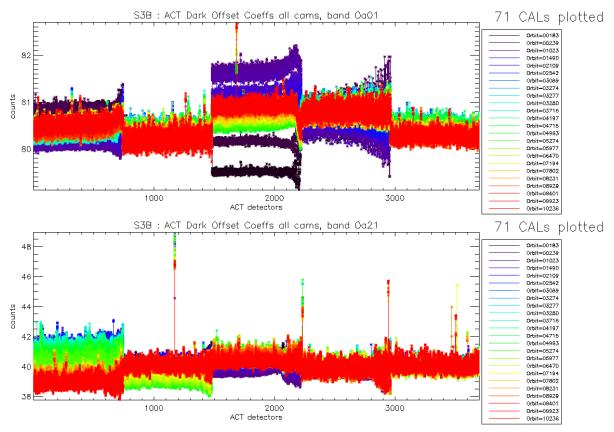


Figure 16: OLCI-B Dark Offset for band Oa1 (top) and Oa21 (bottom), all radiometric calibrations so far except the first one (orbit 167) for which the instrument was not thermally stable yet.



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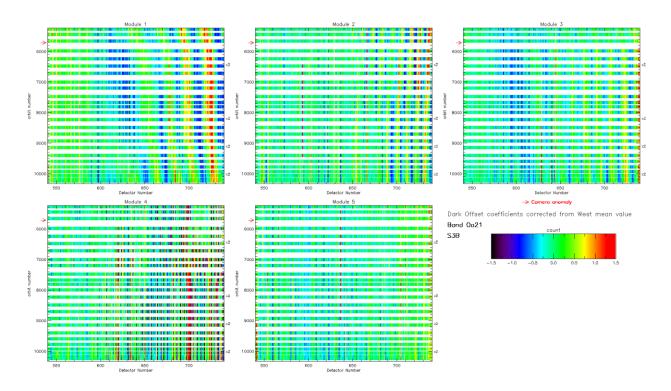


Figure 17: OLCI-B map of periodic noise for the 5 cameras, for band Oa21. X-axis is detector number (East part, from 540 to 740, where the periodic noise occurs), Y-axis is the orbit number. The counts have been corrected from the West detectors mean value (not affected by periodic noise) in order to remove mean level gaps and consequently to have a better visualisation of the long term evolution of the periodic noise structure.

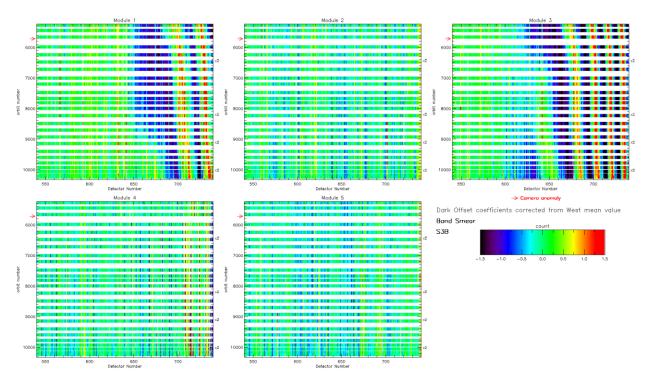


Figure 18: same as Figure 17 for smear band.

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Dark Currents

As for OLCI-A there is no significant evolution of the Dark Current coefficients (Figure 19) during the current cycle except the small regular increase (almost linear), for all detectors, since the beginning of the mission (see Figure 20) probably due to an increase of hot pixels (see Figure 21).



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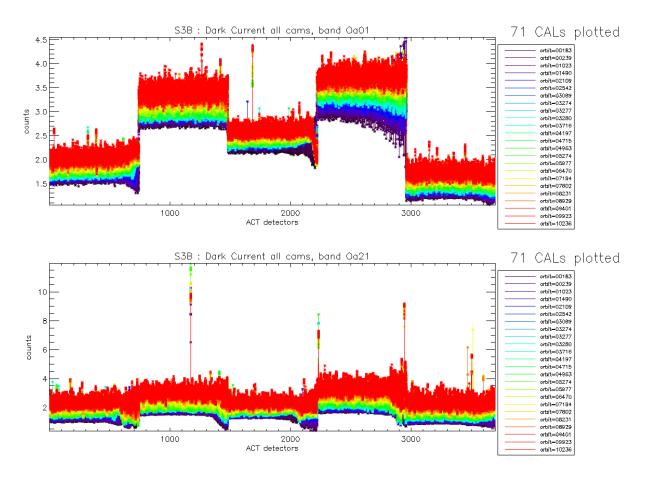


Figure 19: OLCI-B Dark Current for band Oa1 (top) and Oa21 (bottom), all radiometric calibrations so far except the first one (orbit 167) for which the instrument was not thermally stable yet.

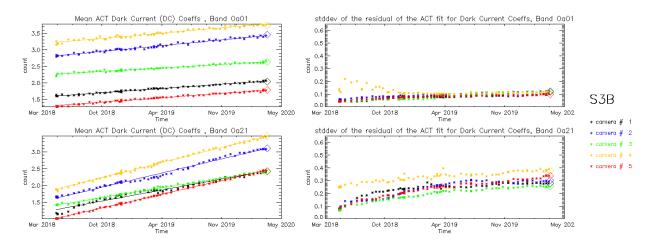


Figure 20: left column: ACT mean on 400 first detectors of OLCI-B Dark Current coefficients for spectral band Oa01 (top) and Oa21 (bottom). Right column: same as left column but for Standard deviation instead of mean.

We see an increase of the DC level as a function of time especially for band Oa21.

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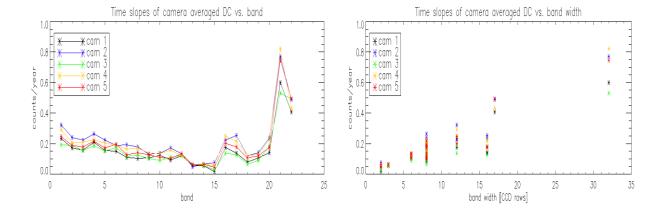


Figure 21: OLCI-B Dark Current increase rates with time (in counts per year) vs. band (left) and vs. band width (right)

2.2.2 Instrument response and degradation modelling [OLCI-L1B-CV-250]

2.2.2.1 Instrument response monitoring

2.2.2.1.1 OLCI-A

Figure 22 shows the gain coefficients of every pixel for two OLCI-A channels, Oa1 (400 nm) and Oa21 (1020 nm), highlighting the significant evolution of the instrument response since early mission.



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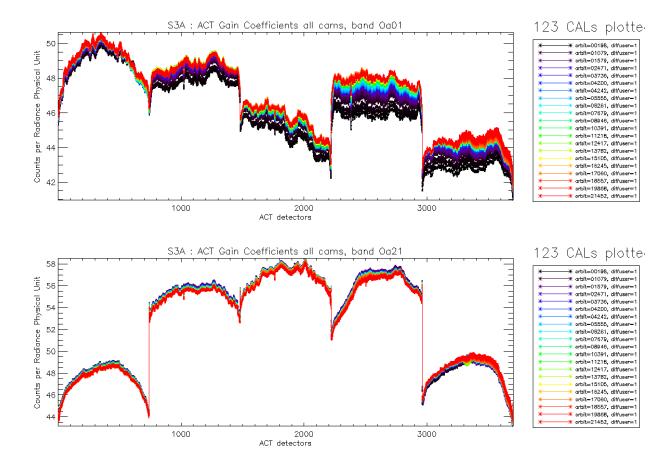


Figure 22: OLCI-A Gain Coefficients for band Oa1 (top) and Oa21 (bottom), all diffuser 1 radiometric calibrations so far except the first one (orbit 183) for which the instrument was not thermally stable yet.

The gains plotted in Figure 22, however are derived using the ground BRDF model which is known to suffer from illumination geometry dependent residual errors (see previous Cyclic Reports for more details). Consequently they are post-processed to replace the ground BRDF model by the in-flight version, based on Yaw Manoeuvres data, prior to determine the radiometric evolution.

Figure 23 displays a summary of the time evolution derived from post-processed gains: the cross-track average of the BRDF corrected gains (taking into account the diffuser ageing) is plotted as a function of time, for each module, relative to a given reference calibration (the 07/12/2016). It shows that, if a significant evolution occurred during the early mission, the trends tend to stabilize, with the exception of band 1 of camera 1 and 4.

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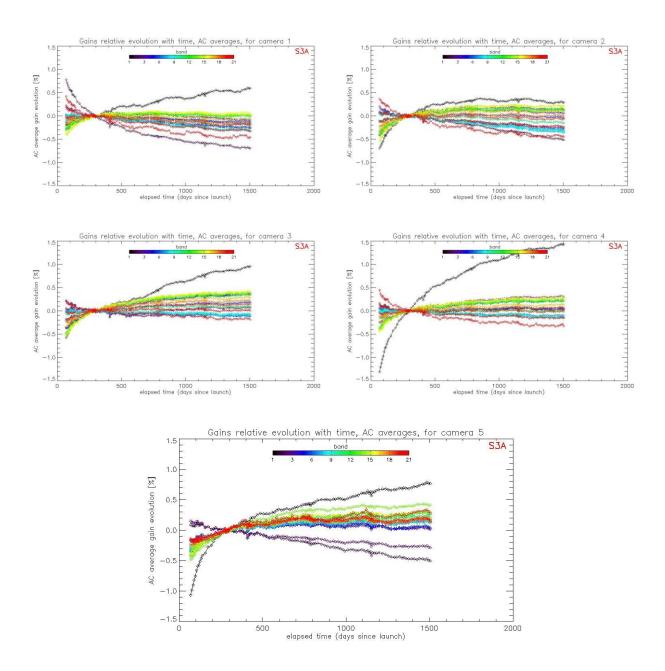


Figure 23: camera averaged gain relative evolution with respect to "best geometry" calibration (07/12/2016), as a function of elapsed time since the change in OLCI channels settings (25/04/16); one curve for each band (see colour code on plots), one plot for each module. The diffuser ageing has been taken into account.

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2.2.2.1.2 OLCI-B

Figure 24 shows the gain coefficients of every pixel for two OLCI-B channels, Oa1 (400 nm) and Oa21 (1020 nm), highlighting the significant evolution of the instrument response since early mission.

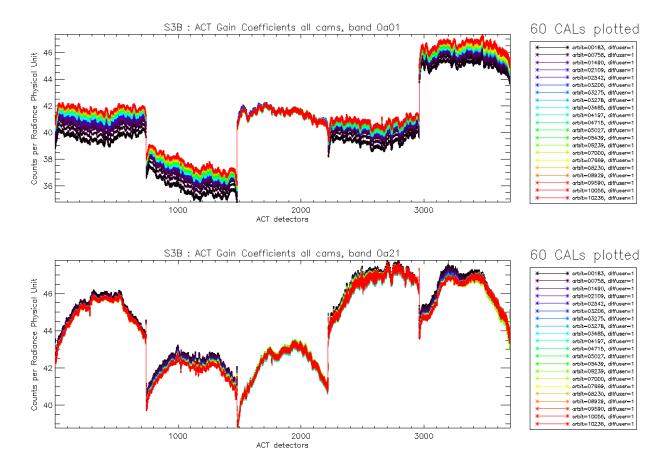


Figure 24: OLCI-B Gain Coefficients for band Oa1 (top) and Oa21 (bottom), all diffuser 1 radiometric calibrations so far except the first one (orbit 167) for which the instrument was not thermally stable yet.

Figure 25 displays a summary of the time evolution derived from post-processed gains: the cross-track average of the BRDF corrected gains is plotted as a function of time, for each module, relative to a given reference calibration (first calibration after channel programming change: 18/06/2018). It shows that, if a significant evolution occurred during the early mission, the trends tend to stabilize. The large amount of points near elapsed time = 220 days is due to the yaw manoeuvre campaign.

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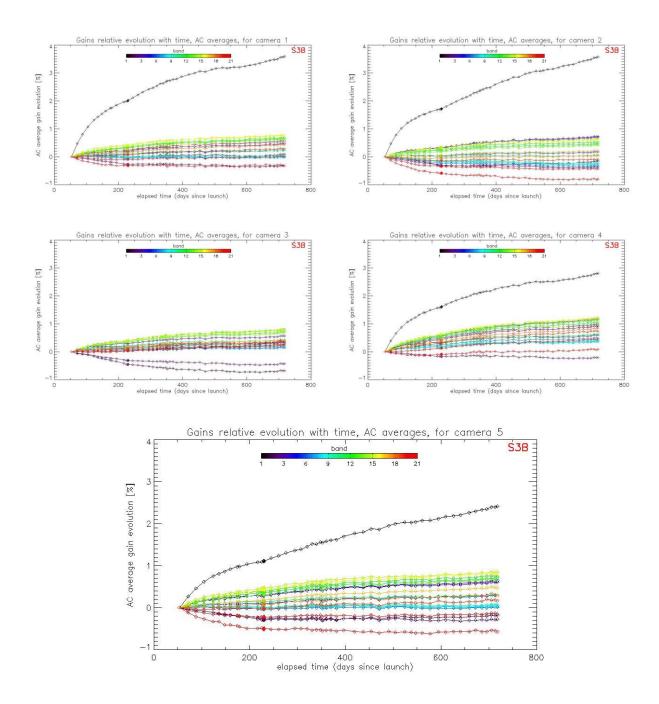


Figure 25: OLCI-B camera averaged gain relative evolution with respect to first calibration after channel programming change (18/06/2018), as a function of elapsed time since the beginning of the mission; one curve for each band (see colour code on plots), one plot for each module. The diffuser ageing has been taken into account.



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2.2.2.2 Instrument evolution modelling

2.2.2.2.1 OLCI-A

The OLCI-A Radiometric Model has been refreshed and put in operations the 29/10/2019 (Processing Baseline 2.58). The model has been derived on the basis of an extended Radiometric Calibration dataset (from 25/04/2016 to 28/08/2019). It includes the correction of the diffuser ageing for the six bluest bands (Oa1 to Oa6) for which it is clearly measurable. The model performance over the complete dataset (including the 15 calibrations in extrapolation over about 8 months), despite a very small drift with respect to the most recent data, remains better than 0.11% (at the exception of band Oa01 for the very first CAL) when averaged over the whole field of view (Figure 26). The previous model, trained on a Radiometric Dataset limited to 11/04/2019, shows clearly a bigger drift of the model with respect to most recent data (Figure 27). Comparison of the two figures shows the improvement brought by the updated Model over almost all the mission: only Oa01 show a lower performance for the very first calibration with the new model.

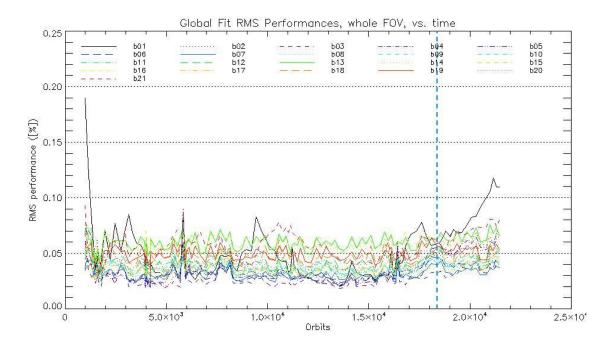


Figure 26: RMS performance of the OLCI-A Gain Model of the current processing baseline as a function of orbit.

The blue vertical dotted lines defines the limit from which the gain model starts to be extrapolated (i.e. it corresponds to the most recent CAL of the dataset used to build the model).



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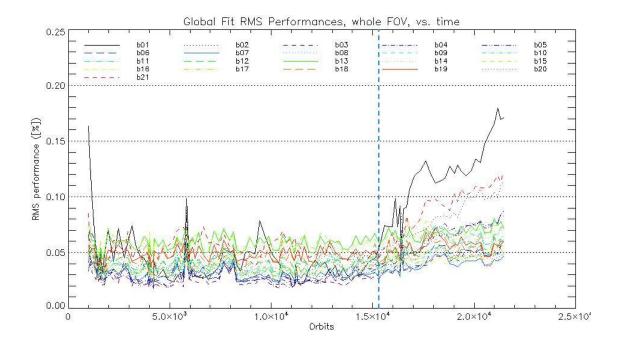


Figure 27: RMS performance of the OLCI-A Gain Model of the previous Processing Baseline as a function of orbit.

The overall instrument evolution since channel programming change (25/04/2016) is shown on Figure 28.

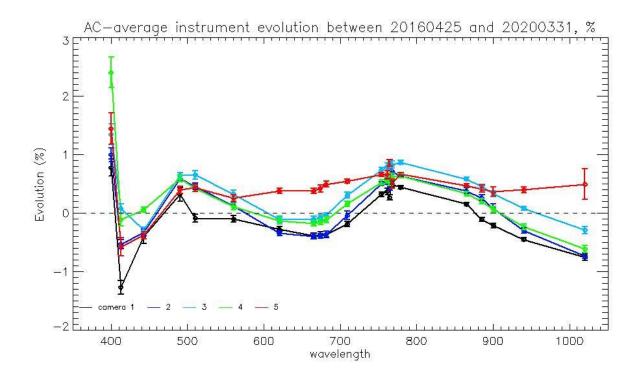


Figure 28: OLCI-A Camera-averaged instrument evolution since channel programming change (25/04/2016) and up to most recent calibration (31/03/2020) versus wavelength.



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The overall per camera performance, as a function of wavelength, and at each orbit is shown on Figure 29 as the average and standard deviation of the model over data ratio.

Finally, Figure 30 to Figure 32 show the detail of the model performance, with across-track plots of the model over data ratios at each orbit, one plot for each channel.

Comparisons of Figure 30 to Figure 32 with their counterparts in Report of Cycle 49 clearly demonstrate the improvement brought by the new model whatever the level of detail.

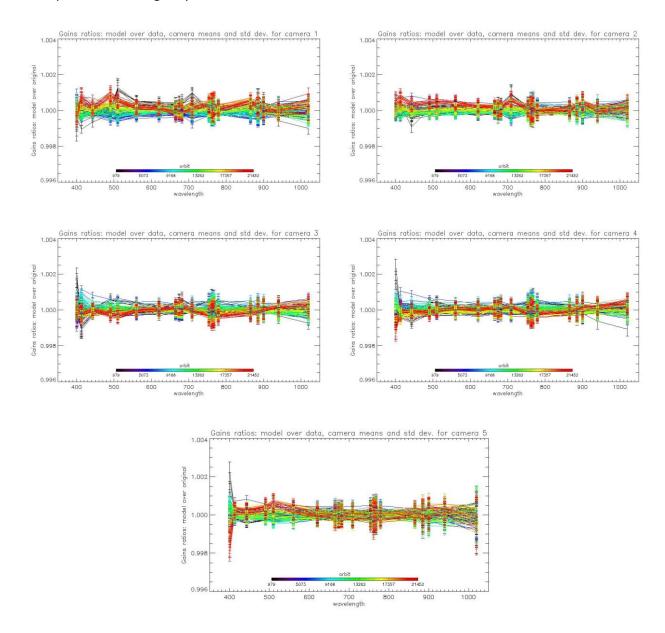


Figure 29: For the 5 cameras: OLCI-A Evolution model performance, as camera-average and standard deviation of ratio of Model over Data vs. wavelength, for each orbit of the test dataset, including 15 calibrations in extrapolation, with a colour code for each calibration from blue (oldest) to red (most recent).

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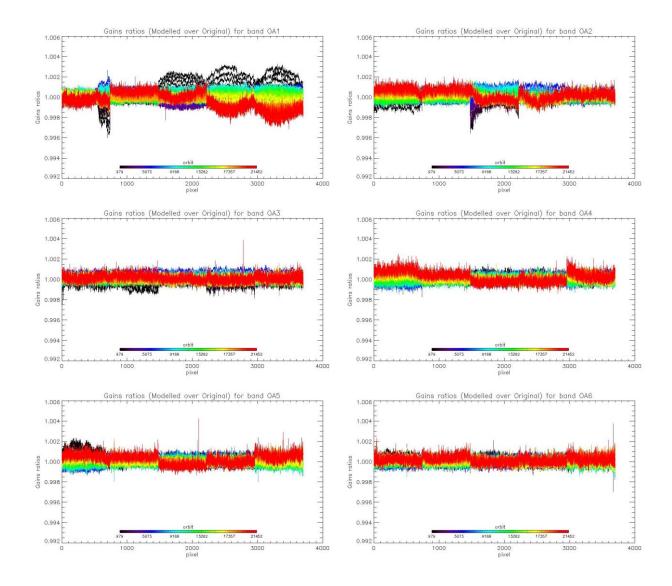


Figure 30: Evolution model performance, as ratio of Model over Data vs. pixels, all cameras side by side, over the whole current calibration dataset (since instrument programing update), including 15 calibrations in extrapolation, channels Oa1 to Oa6.

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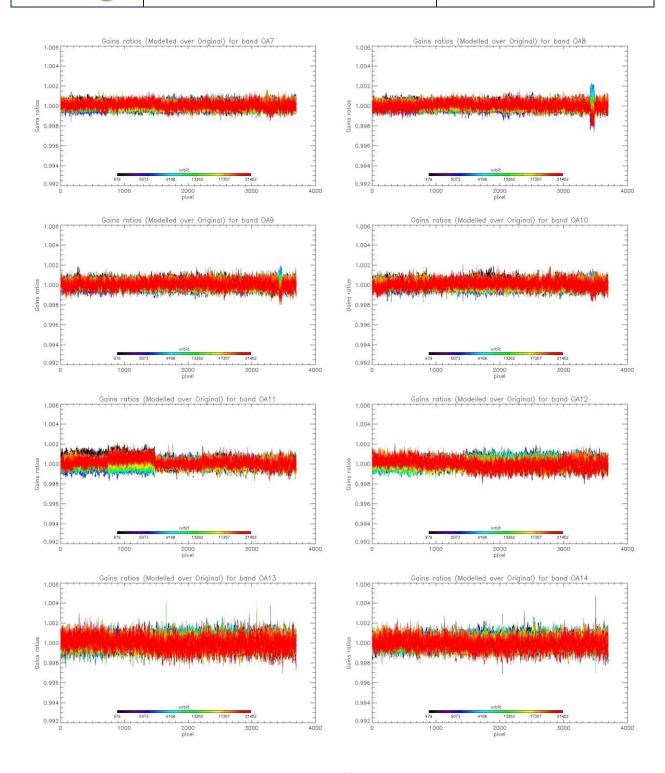


Figure 31: same as Figure 30 for channels Oa7 to Oa14.

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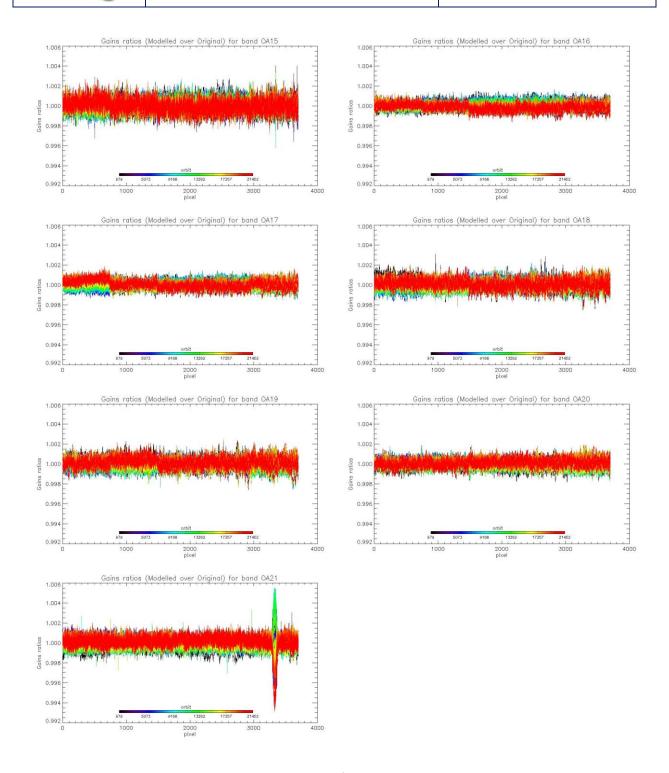


Figure 32: same as Figure 30 for channels Oa15 to Oa21.



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2.2.2.2. OLCI-B

Instrument response and degradation modelling for OLCI-B, including the use of the in-flight BRDF model (based on 11th December 2018 Yaw Manoeuvres), has been refreshed and deployed at PDGS on 29th October 2019 (Processing Baseline 1.30). The model has been derived on the basis of an extended Radiometric Calibration dataset (from 11/05/2018 to 02/10/2019). It includes the correction of the diffuser ageing for the five bluest bands (Oa1 to Oa5) for which it is clearly measurable. The model performance over the complete dataset (including the 15 calibrations in extrapolation over about 7 months) is illustrated in Figure 33. Despite a small drift with respect to the most recent data, it remains better than 0.10% when averaged over the whole field of view for all band except Oa01 (<0.15%). The previous model, trained on a Radiometric Dataset limited to 27/02/2019, shows a stronger drift of the model with respect to most recent data, especially for band Oa01 (Figure 34). Comparison of the two figures shows the improvement brought by the updated Model over all the mission.

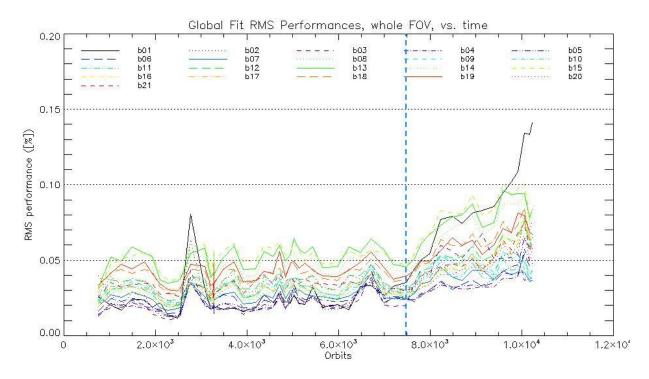


Figure 33: RMS performance of the OLCI-B Gain Model of the current processing baseline as a function of orbit.

The blue vertical dotted lines defines the limit from which the gain model starts to be extrapolated (i.e. it corresponds to the most recent CAL of the dataset used to build the model).

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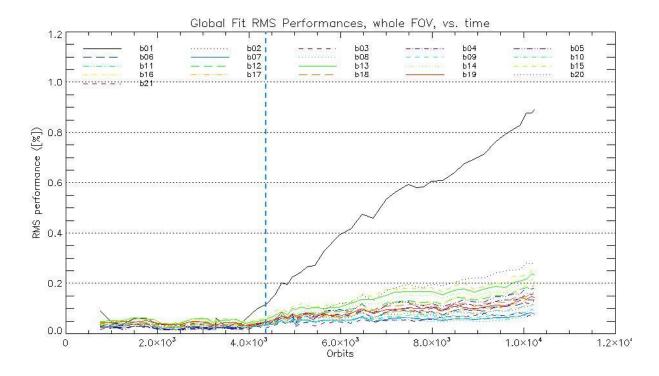


Figure 34: RMS performance of the OLCI-B Gain Model of the previous processing baseline as a function of orbit (please note the different vertical scale with respect to Figure 33).



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The overall instrument evolution since channel programming change (18/06/2018) is shown on Figure 35.

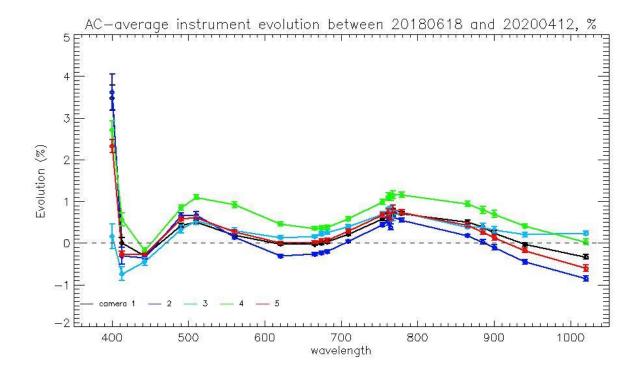


Figure 35: OLCI-B Camera-averaged instrument evolution since channel programming change (18/06/2018) and up to most recent calibration (12/04/2020) versus wavelength.

The overall per camera performance, as a function of wavelength, and at each orbit is shown on Figure 36 as the average and standard deviation of the model over data ratio.

Finally, Figure 37 to Figure 39 show the detail of the model performance, with across-track plots of the model over data ratios at each orbit, one plot for each channel.

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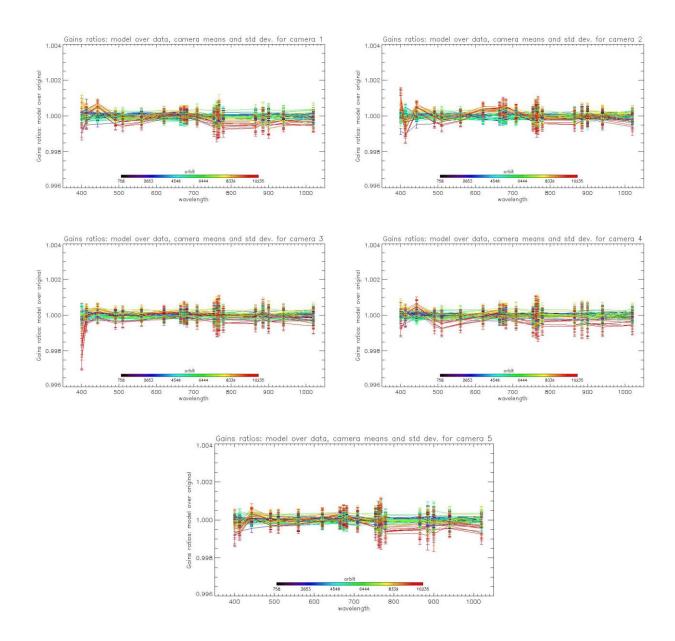


Figure 36: For the 5 cameras: OLCI-B Evolution model performance, as camera-average and standard deviation of ratio of Model over Data vs. wavelength, for each orbit of the test dataset, including 15 calibrations in extrapolation, with a colour code for each calibration from blue (oldest) to red (most recent).

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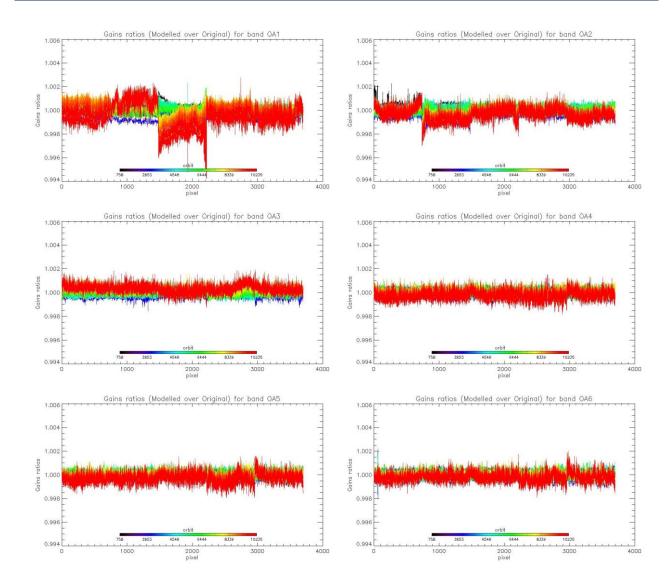


Figure 37: Evolution model performance, as ratio of Model over Data vs. pixels, all cameras side by side, over the whole current calibration dataset (since instrument programming update), including 15 calibrations in extrapolation, channels Oa1 to Oa6.

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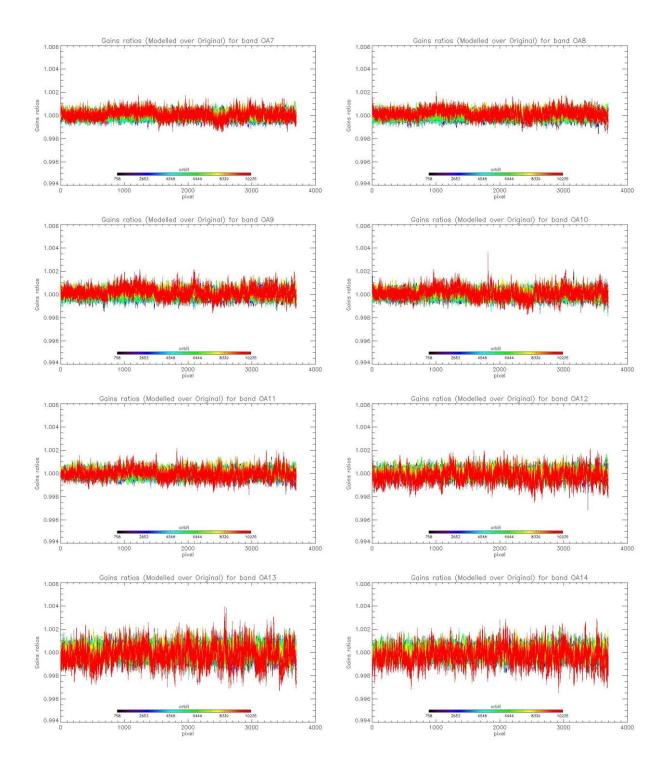


Figure 38: same as Figure 37 for channels Oa7 to Oa14.

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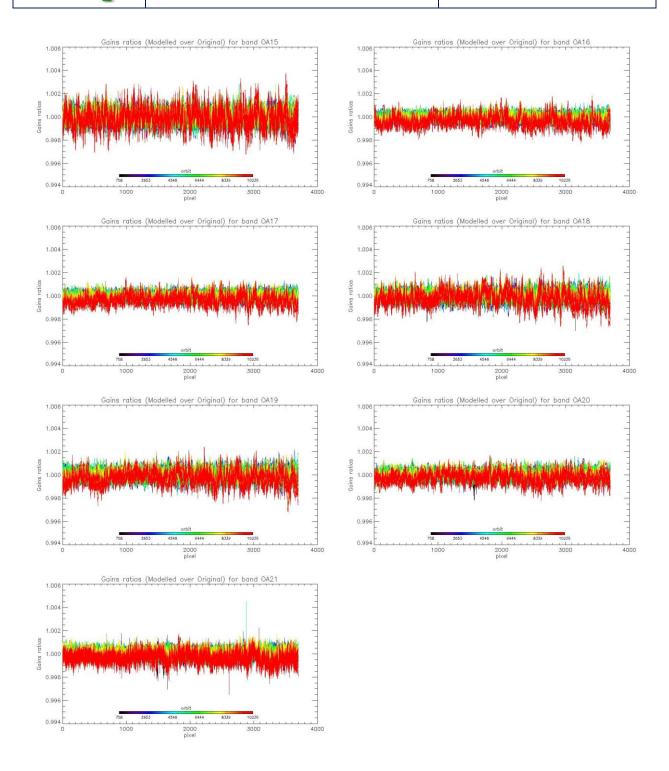


Figure 39: same as Figure 37 for channels Oa15 to Oa21.

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2.2.3 Ageing of nominal diffuser [OLCI-L1B-CV-240]

2.2.3.1 OLCI-A

There has been one calibration sequence S05 (reference diffuser) for OLCI-A during acquisition cycle 056:

S01 sequence (diffuser 1) on 31/03/2020 05:07 to 05:09 (absolute orbit 21452)

With the associated S01 sequence (nominal diffuser) in order to compute ageing:

S05 sequence (diffuser 2) on 31/03/2020 06:48 to 06:50 (absolute orbit 21453)

The diffuser 1 Ageing is computed for each 3700 detector and each spectral band by formula:

Ageing(orb)=G1(orb)/G2(orb)-G1(orb_ref)/G2(orb_ref)

Where:

- G1 is the diffuser 1 (= nominal diffuser) Gain coefficients
- G2 is the diffuser 2 (= reference diffuser) Gain coefficients
- orb_ref is a reference orbit chosen at the beginning of the mission

Ageing is represented in Figure 40 for band Oa01 and in Figure 41 for band Oa17. The negative shift of the sequence at orbit 5832 (for which a slight increase would be expected instead) is not explained so far and still under investigation. It should be noted that the corresponding orbit of diffuser 1 (nominal) has also been detected as an outlier in the modelling of the radiometric long-term trend with an unexpected excess of brightness.

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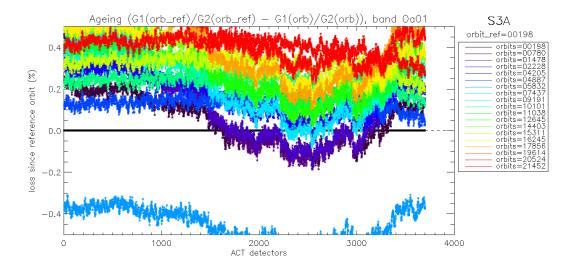


Figure 40: diffuser 1 ageing for spectral band Oa01. We see strong ACT low frequency structures that are due to residual of BRDF modelling.

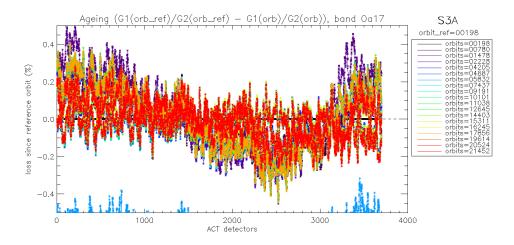


Figure 41: same as Figure 40 for spectral band Oa17. We use this band in order to normalize other bands and remove the ACT structures due to residual of BRDF modelling. Normalized curve for spectral band Oa01 is presented in Figure 42.

Figure 40 and Figure 41 show that the Ageing curves are impacted by a strong ACT pattern which is due to residuals of the bad modelling (on-ground) of the diffuser BRDF. This pattern is dependant of the azimuth angle. It is a 'white' pattern which means it is the same for all spectral bands. As such, we can remove this pattern by normalizing the ageing of all bands by the curve of band Oa17 which is expected not to be impacted by ageing because in the red part of the spectrum. We use an ACT smoothed version (window of 100 detectors) of band Oa17 in order to reduce the high frequency noise. Normalized ageing for spectral band Oa01 is represented in Figure 42 where we can see that this band is impacted by ageing of the diffuser.



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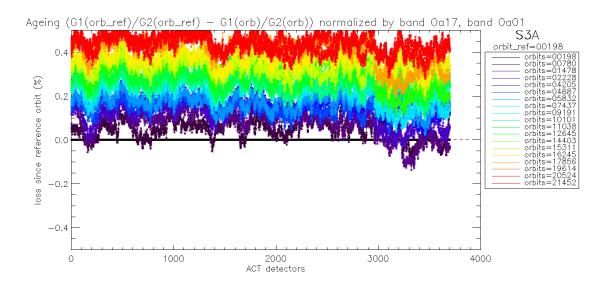


Figure 42: same as Figure 40 after normalization by band Oa17. Ageing of the diffuser 1 is now visible in the 5 cameras.

Camera averaged ageing (normalized by band Oa17) as a function of wavelength is represented in Figure 43 where we can see that ageing is stronger in the 'bluest' spectral bands (short wavelengths). Ageing is clearly visible only for the 6 first spectral bands so far in the OLCI mission life.

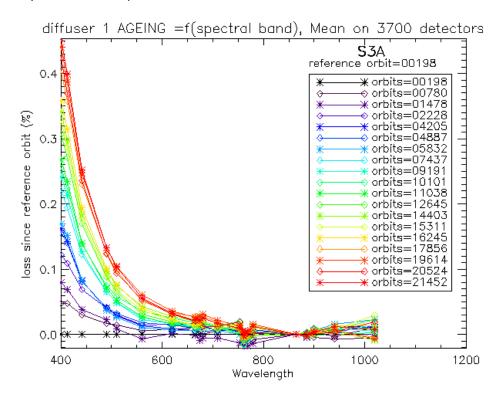


Figure 43: Diffuser 1 ageing as a function of wavelength (or spectral band). Ageing is clearly visible in spectral band #1 to #5.



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Figure 44 shows the evolution, for spectral band Oa01, of the 5 cameras averaged ageing as a function of time.

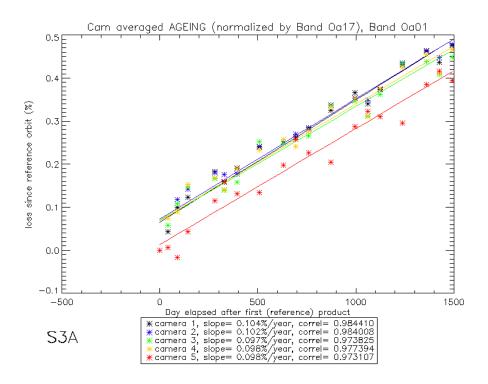


Figure 44: Camera averaged ageing for band Oa01 (normalized by band Oa17) as a function of elapsed time.

Linear fit for each camera is plotted. The slope (% loss per year) and the correlation coefficient.

A model of diffuser ageing as a function of cumulated exposure time (i.e. number of acquisition sequence on nominal diffuser, regardless of the band setting) has been built and is described in Cyclic #23 Report. The results of this model confirm the need to model ageing against cumulated exposure rather than elapsed time, as it provides a more linear trend, even if not perfect (see Figure 21 of Cyclic #23 Report).

The slope of this ageing model (% of loss per exposure) as a function of wavelength is presented in Figure 45).



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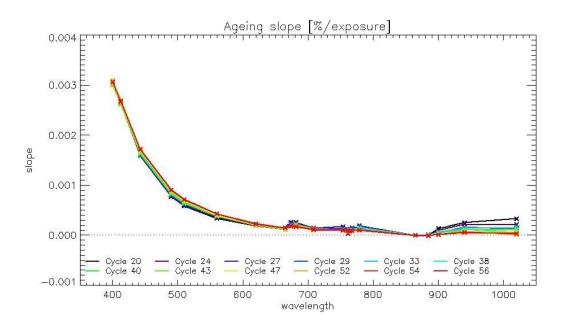


Figure 45: Slope of ageing fit (% of loss per exposure) vs wavelengths, using all the available ageing sequence at the time of the current cycle (red curve) and at the time of previous cycle for which an ageing sequence was measured (see legend within the figure).

In Figure 45, we see that the Ageing slopes have not significantly changed between the current Cycle and the last eleven cycles with a S05 sequence (cycles #54, #52, #47, #43, #40, #38, #33, #29, #27, #24 and #20). Cycle #47 has been used to derive the Ageing Correction model used for the currently operational Gain Model. The exposure time dependent ageing model is used to derive the Gain Model, the most recent version of which has been put in operations in PDGS on 29th October 2019.

2.2.3.2 OLCI-B

There has been one calibration sequence S05 (reference diffuser) for OLCI-B during acquisition Cycle 037:

S01 sequence (diffuser 1) on 31/03/2020 01:05 to 01:07 (absolute orbit 10056)

With the associated S01 sequence (nominal diffuser) in order to compute ageing:

\$ S05 sequence (diffuser 2) on 31/03/2020 02:46 to 02:48 (absolute orbit 10057)

The diffuser 1 Ageing is computed for each 3700 detector and each spectral band by formula:

Ageing(orb)=G1(orb)/G2(orb)-G1(orb_ref)/G2(orb_ref)

Where:

- G1 is the diffuser 1 (= nominal diffuser) Gain coefficients
- G2 is the diffuser 2 (= reference diffuser) Gain coefficients



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orb_ref is a reference orbit chosen at the beginning of the mission

Ageing is represented in Figure 46 for band Oa01 and in Figure 47 for band Oa17.

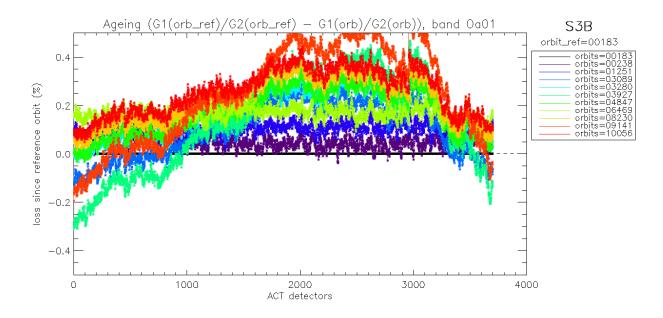


Figure 46: OLCI-B diffuser 1 ageing for spectral band Oa01. We see strong ACT low frequency structures that are due to residual of BRDF modelling.

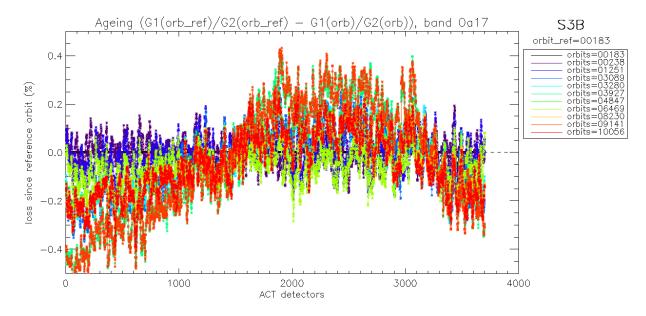


Figure 47: same as Figure 46 for spectral band Oa17. We use this band in order to normalize other bands and remove the ACT structures due to residual of BRDF modelling. Normalized curve for spectral band Oa01 is presented in Figure 48.



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Figure 46 and Figure 47 show that the Ageing curves are impacted by a strong ACT pattern which is due to residuals of the bad modelling (on-ground) of the diffuser BRDF. This pattern is dependant of the azimuth angle. It is a 'white' pattern which means it is the same for all spectral bands. As such, we can remove this pattern by normalizing the ageing of all bands by the curve of band Oa17 which is expected not to be impacted by ageing because in the red part of the spectrum. We use an ACT smoothed version (window of 100 detectors) of band Oa17 in order to reduce the high frequency noise. Normalized ageing for spectral band Oa01 is represented in Figure 48 where we can see that this band is impacted by ageing of the diffuser.

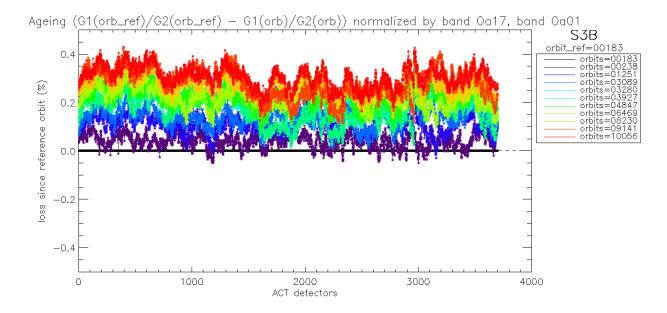


Figure 48: same as Figure 46 after normalization by band Oa17. Ageing of the diffuser 1 is now visible in the 5 cameras.

Camera averaged ageing (normalized by band Oa17) as a function of wavelength is represented in Figure 49 where we can see that ageing is stronger in the 'bluest' spectral bands (short wavelengths). Ageing is clearly visible only for the 5 first spectral bands so far in the OLCI mission life. We see a bump around 680 nm which is probably due to characterisation errors that are strongly geometry dependant and affect differently the various camera. This behaviour is under investigation.

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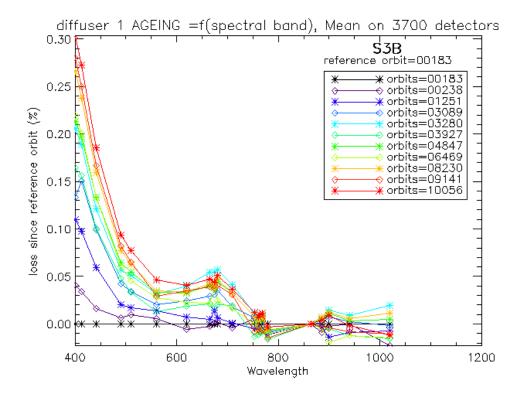


Figure 49: OLCI-B Diffuser 1 ageing as a function of wavelength (or spectral band). Ageing is clearly visible in spectral band #1 to #5.

As for OLCI-A, the OLCI-B Diffuser Ageing has been modelled as a function of cumulated exposure time (i.e. number of acquisition sequence on nominal diffuser, regardless of the band setting). The OLCI-A modelling methodology has been applied to OLCI-B. The results of this modelling, iterated at each new Ageing Sequence acquisition, expressed as the rate of ageing (% of loss per exposure) as a function of wavelength is presented in Figure 50).

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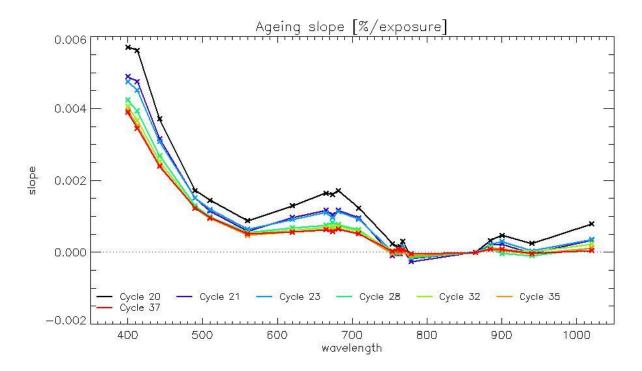


Figure 50: Slope of ageing fit (% of loss per exposure) vs wavelengths, using all the available ageing sequence at the time of the current cycle (red curve) and at the time of previous cycle for which an ageing sequence was measured (see legend within the figure).

In Figure 50, we see that the Ageing slopes have significantly changed between the current Cycle and the last five cycles with a S05 sequence (cycles #35, #32, #28, #23, #21, #20). However, the behaviour tends to stabilize. The slope in the high wavelengths bands (red, NIR) is close to 0 in the three last cycles which is the expected behaviour (No Ageing expected at high wavelength). A workaround has been used instead of the nominal Ageing Assessment and modelling to allow accounting for Diffuser Ageing in the Radiometric Gain Model. Ageing was assessed by direct comparisons of two nominal diffuser observations, acquired under the same geometry (i.e. directly comparable) and the same day (i.e. with no significant instrument sensitivity evolution) but separated by 7 more exposures to light (during the Yaw Manoeuvres dedicated to the in-flight BRDF modelling). This exposure time dependent ageing model is used to derive the Gain Model, the most recent version of which has been put in operations in PDGS on 29th October 2019.

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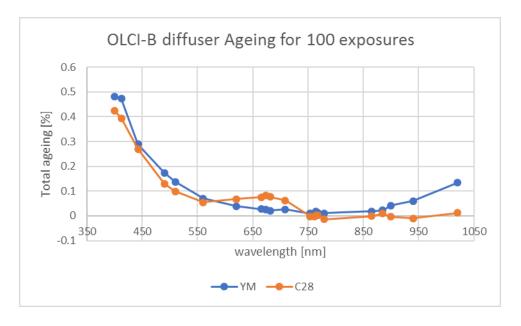


Figure 51: OLCI-B diffuser ageing (after 100 exposures, i.e. about two years) according to direct assessment from Yaw Manoeuvres (blue) and nominal method at Cycle 28 (orange).

2.2.4 Updating of calibration ADF [OLCI-L1B-CV-260]

2.2.4.1.1 OLCI-A

No CAL_AX ADF has been delivered to PDGS during the report period.

2.2.4.1.2 OLCI-B

One CAL_AX ADF has been delivered to PDGS (processing baseline 1.38) during the report period:

S3B_OL_1_CAL_AX_20200321T171527_20991231T235959_20200331T120000______MPC_O_AL_010.SEN3

It includes the update of the dark LUTs as well as the Geometric Calibration Model (GCM). The source for the Dark LUT is the S01 calibration measurement from 21/03/2020 17h15.

2.2.5 Radiometric Calibrations for sun azimuth angle dependency and Yaw Manoeuvres for Solar Diffuser on-orbit re-characterization [OLCI-L1B-CV-270 and OLCI-L1B-CV-280]

2.2.5.1.1 OLCI-A

This activity has not evolved during cycle 056 and results presented in Cycle 15 report are still valid.

2.2.5.1.2 OLCI-B

Activity has started for S3B-OLCI. The SAA domain explored is now increased by the acquisitions from the Yaw Manoeuvres and analysis becomes meaningful. Analysis is on-going.

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2.3 Spectral Calibration [OLCI-L1B-CV-400]

2.3.1 OLCI-A

There has been no Spectral Calibration (S02 + S03, S09) acquisition for OLCI-A during acquisition cycle 056.

The last results presented in Cyclic Report #54/#35 (S3A/S3B) stay valid.

2.3.2 OLCI-B

There has been no Spectral Calibration (S02 + S03, S09) acquisition for OLCI-B during acquisition Cycle 037.

The last results presented in Cyclic Report #54/#35 (S3A/S3B) stay valid.

2.4 Signal to Noise assessment [OLCI-L1B-CV-620]

2.4.1 SNR from Radiometric calibration data

2.4.1.1 OLCI-A

SNR computed for all calibration data (S01, S04 and S05 sequences) as a function of band number is presented in Figure 52.

SNR computed for all calibration data as a function of orbit number for band Oa01 (the less stable band) is presented in Figure 53.

There is no significant evolution of this parameter during the current cycle and the ESA requirement is fulfilled for all bands.

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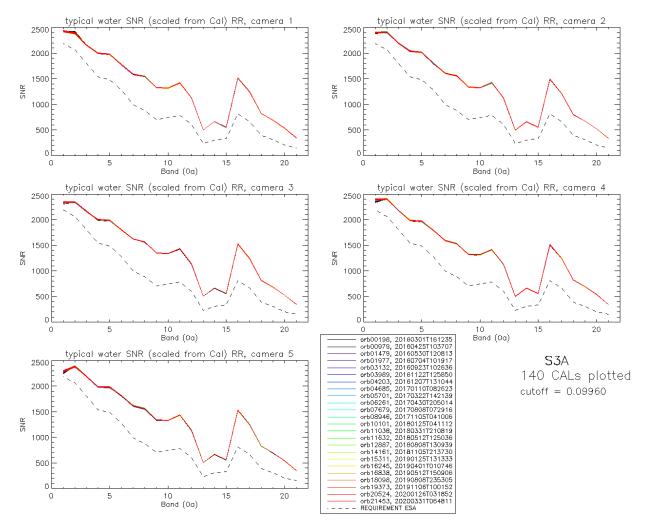


Figure 52: OLCI-A Signal to Noise ratio as a function of the spectral band for the 5 cameras. These results have been computed from radiometric calibration data. All calibrations except first one (orbit 183) are presents with the colours corresponding to the orbit number (see legend). The SNR is very stable with time: the curves for all orbits are almost superimposed. The dashed curve is the ESA requirement.

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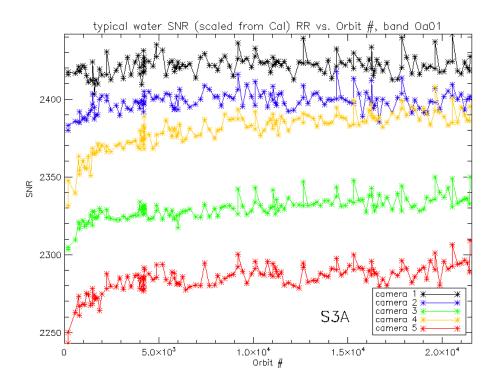


Figure 53: long-term stability of the SNR estimates from Calibration data, example of channel Oa1.

The mission averaged SNR figures are provided in Table 1 below, together with their radiance reference level. According to the OLCI SNR requirements, these figures are valid at these radiance levels and at Reduced Resolution (RR, 1.2 km). They can be scaled to other radiance levels assuming shot noise (CCD sensor noise) is the dominating term, i.e. radiometric noise can be considered Gaussian with its standard deviation varying as the square root of the signal; in other words: $SNR(L) = SNR(L_{ref}) \cdot \sqrt{\frac{L}{L_{ref}}}$. Following the same assumption, values at Full Resolution (300m) can be derived from RR ones as 4 times smaller.



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Table 1: OLCI-A SNR figures as derived from Radiometric Calibration data. Figures are given for each camera (time average and standard deviation), and for the whole instrument. The requirement and its reference radiance level are recalled (in mW.sr⁻¹.m⁻².nm⁻¹).

	L_{ref}	SNR	C1		C2		C3		C4		C5		All	
	∟ ref	SIVIL	CI		CZ		CJ		CŦ				All	
nm	LU	RQT	avg	std	avg	std	avg	std	avg	std	avg	std	avg	std
400.000	63.0	2188	2421	6.3	2398	6.5	2330	7.5	2380	12.0	2284	9.5	2363	7.1
412.000	74.1	2061	2390	8.7	2406	5.8	2339	4.7	2401	4.9	2383	8.1	2384	4.8
442.000	65.6	1811	2160	5.2	2198	5.7	2164	4.8	2186	4.2	2195	5.2	2180	3.6
490.000	51.2	1541	2000	4.6	2037	5.2	1997	4.2	1983	4.5	1988	4.7	2001	3.4
510.000	44.4	1488	1980	5.2	2014	4.7	1985	4.6	1967	4.6	1985	4.5	1986	3.6
560.000	31.5	1280	1776	4.5	1802	4.1	1803	4.8	1794	4.0	1818	3.4	1799	3.1
620.000	21.1	997	1591	4.0	1609	4.0	1624	3.2	1593	3.2	1615	3.6	1607	2.6
665.000	16.4	883	1546	4.0	1558	4.3	1567	3.8	1533	3.6	1561	3.9	1553	3.0
674.000	15.7	707	1329	3.4	1337	3.6	1350	2.8	1323	3.2	1342	3.6	1336	2.5
681.000	15.1	745	1319	3.6	1326	3.1	1338	2.7	1314	2.5	1333	3.6	1326	2.2
709.000	12.7	785	1421	4.3	1420	4.0	1435	3.4	1414	3.5	1430	3.1	1424	2.8
754.000	10.3	605	1127	3.2	1121	3.0	1135	3.4	1125	2.6	1139	2.9	1129	2.4
761.000	6.1	232	502	1.1	498	1.2	505	1.2	500	1.1	508	1.4	503	0.9
764.000	7.1	305	663	1.6	658	1.6	668	2.1	661	1.5	670	2.2	664	1.4
768.000	7.6	330	558	1.5	554	1.3	562	1.3	557	1.4	564	1.4	559	1.1
779.000	9.2	812	1516	4.8	1498	4.8	1525	5.3	1511	5.0	1526	5.0	1515	4.3
865.000	6.2	666	1244	3.6	1213	3.5	1239	4.0	1246	3.6	1250	2.8	1238	2.9
885.000	6.0	395	823	1.6	801	1.7	814	2.0	824	1.5	831	1.7	819	1.1
900.000	4.7	308	691	1.6	673	1.3	683	1.7	693	1.5	698	1.5	688	1.0
940.000	2.4	203	534	1.1	522	1.1	525	0.9	539	1.1	542	1.3	532	0.7
1020.000	3.9	152	345	0.9	337	0.9	348	0.7	345	0.8	351	0.8	345	0.5



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2.4.1.2 OLCI-B

SNR computed for all OLCI-B calibration data (S01, S04 (but not the dark-only S04) and S05 sequences) as a function of band number is presented in Figure 54.

SNR computed for all OLCI-B calibration data as a function of orbit number for band Oa01 (the less stable band) is presented in Figure 55.

As for OLCI-A the SNR is very stable in time. There is no significant evolution of this parameter during the current cycle and the ESA requirement is fulfilled for all bands.

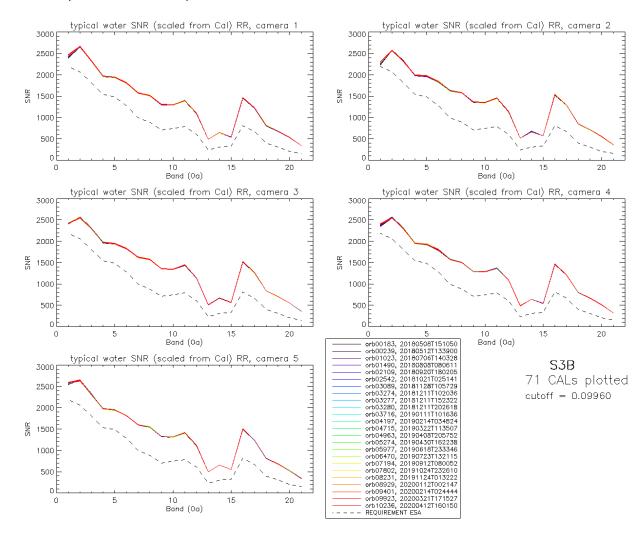


Figure 54: OLCI-B Signal to Noise ratio as a function of the spectral band for the 5 cameras. These results have been computed from radiometric calibration data. All calibrations except first one (orbit 167) are presents with the colours corresponding to the orbit number (see legend). The SNR is very stable with time: the curves for all orbits are almost superimposed. The dashed curve is the ESA requirement.

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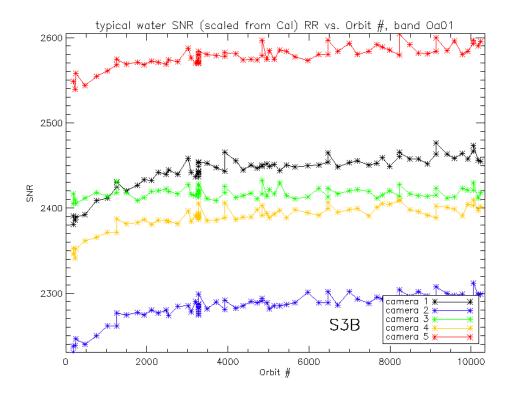


Figure 55: long-term stability of the OLCI-B SNR estimates from Calibration data, example of channel Oa1.



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Table 2: OLCI-B SNR figures as derived from Radiometric Calibration data. Figures are given for each camera (time average and standard deviation), and for the whole instrument. The requirement and its reference radiance level are recalled (in mW.sr⁻¹.m⁻².nm⁻¹).

		CNID	I		co co				-			or.		All	
	L _{ref}	SNR	C1		C2		C3		C4		C5		All		
nm	LU	RQT	avg	std	avg	std	avg	std	avg	std	avg	std	avg	std	
400.000	63.0	2188	2444	20.0	2284	16.5	2417	5.9	2389	14.1	2577	12.7	2422	12.8	
412.000	74.1	2061	2656	6.7	2570	6.0	2548	8.2	2549	5.9	2640	6.9	2593	4.9	
442.000	65.6	1811	2326	6.1	2318	6.1	2302	6.0	2305	6.3	2311	5.9	2313	5.0	
490.000	51.2	1541	1966	4.9	1988	5.9	1971	5.0	1951	4.8	1978	4.9	1971	4.0	
510.000	44.4	1488	1938	5.3	1966	5.6	1943	5.1	1923	5.4	1951	4.9	1944	4.3	
560.000	31.5	1280	1813	5.0	1847	5.5	1829	4.8	1803	5.3	1816	4.6	1822	4.1	
620.000	21.1	997	1573	4.3	1626	4.8	1625	3.9	1576	4.1	1602	3.3	1600	3.0	
665.000	16.4	883	1513	4.1	1579	3.9	1574	4.1	1501	3.2	1547	3.8	1543	2.9	
674.000	15.7	707	1301	3.7	1358	3.9	1353	3.4	1292	2.8	1329	3.1	1327	2.5	
681.000	15.1	745	1293	3.6	1347	3.2	1343	2.9	1285	2.8	1316	2.8	1317	2.1	
709.000	12.7	785	1390	4.4	1447	4.4	1443	4.5	1373	3.1	1412	4.1	1413	3.4	
754.000	10.3	605	1095	4.3	1142	4.0	1141	3.8	1089	3.0	1115	3.8	1116	3.4	
761.000	6.1	232	487	1.3	509	1.3	508	1.4	485	1.2	497	1.5	497	1.1	
764.000	7.1	305	643	1.7	672	2.1	672	2.0	640	1.7	657	2.0	657	1.6	
768.000	7.6	330	541	1.7	567	1.5	564	1.4	540	1.4	554	1.7	553	1.2	
779.000	9.2	812	1466	4.6	1534	4.9	1526	6.0	1465	4.0	1505	4.9	1499	4.2	
865.000	6.2	666	1221	4.0	1286	4.0	1258	4.0	1204	3.7	1238	3.2	1241	3.1	
885.000	6.0	395	808	2.5	847	1.9	834	2.1	798	1.9	814	2.1	820	1.6	
900.000	4.7	308	679	1.5	714	2.1	704	1.6	669	1.6	682	1.6	690	1.2	
940.000	2.4	203	527	1.3	550	1.6	550	1.4	509	1.3	522	1.3	532	1.0	
1020.000	3.9	152	336	0.8	359	1.2	358	0.9	318	0.8	339	1.1	342	0.7	



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2.4.2 SNR from EO data

2.4.2.1 OLCI-A

There has been no update on SNR assessment from EO data during the cycle. Last figures (cycle 9) are considered valid.

2.4.2.2 OLCI-B

The SNR assessment from EO data has not been applied to OLCI-B considering a) that SNR estimates from RC data have been proved more reliable for OLCI-A and b) that it requires a significant amount of human and machine resources that can be more efficiently used for other tasks.

2.5 Geometric Calibration/Validation

2.5.1 OLCI-A

OLCI georeferencing performance was compliant since the introduction of MPC Geometric Calibration, put in production on the 14th of March 2018. It has however significantly improved after its last full revision of GCMs (Geometric Calibration Models, or platform to instrument alignment quaternions) and IPPVMs (Instrument Pixels Pointing Vectors) both derived using the GeoCal Tool.

The following figures (Figure 56 to Figure 61) show time series of the overall RMS performance (requirement criterion) and of the across-track and along-track biases for each camera. New plots (Figure 62 and Figure 63) introduce monitoring of the performance homogeneity within the field of view: georeferencing errors in each direction at camera transitions (difference between last pixel of camera N and first pixel of camera N+1) and within a given camera (maximum bias minus minimum inside each camera). The performance improvement since the 30/07/2019 is significant on most figures: the global RMS value decreases form around 0.35 to about 0.2 (Figure 56), the across-track biases decrease significantly for all cameras (Figure 57 to Figure 61), the along-track bias reduces for at least camera 3 (Figure 59) and the field of view homogeneity improves drastically (Figure 62 and Figure 63, but also reduction of the dispersion – distance between the ± 1 sigma lines – in Figure 57 to Figure 61).



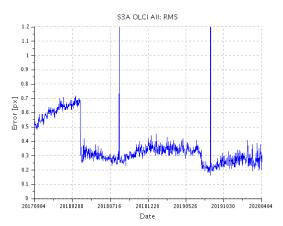
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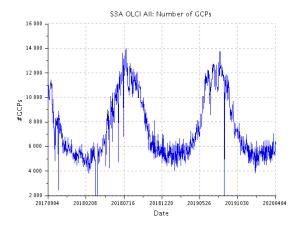
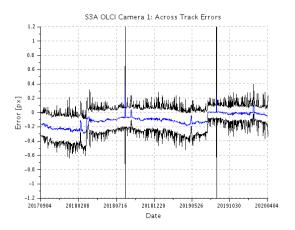


Figure 56: overall OLCI-A georeferencing RMS performance time series (left) and number of validated control points corresponding to the performance time series (right) over the whole monitoring period



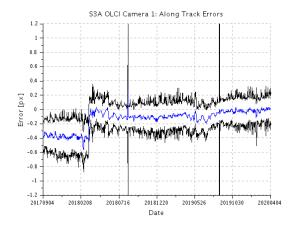
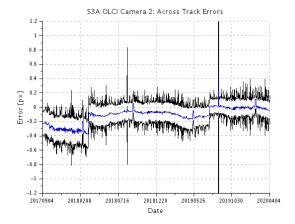


Figure 57: across-track (left) and along-track (right) OLCI-A georeferencing biases time series for Camera 1. Blue line is the average, black lines are average plus and minus 1 sigma.



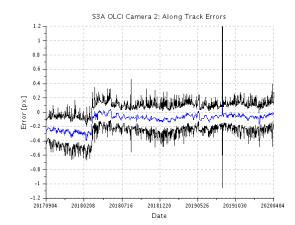


Figure 58: same as Figure 57 for Camera 2.

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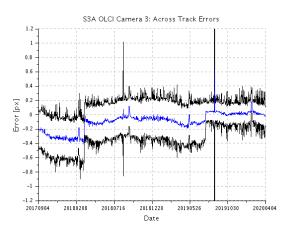
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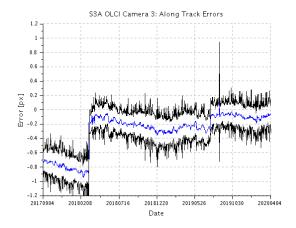
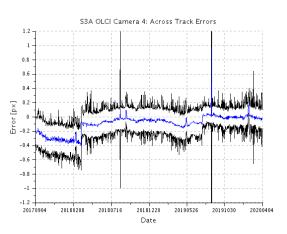


Figure 59: same as Figure 57 for Camera 3.



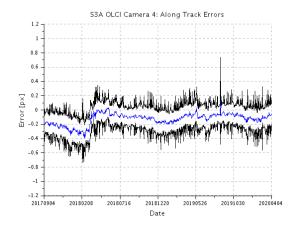
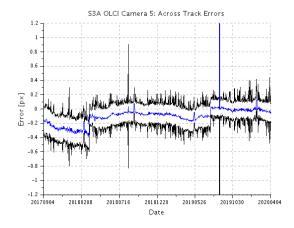


Figure 60: same as Figure 57 for Camera 4.



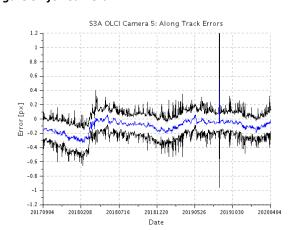


Figure 61: same as Figure 57 for Camera 5.



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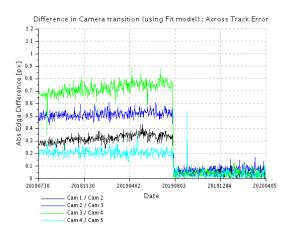
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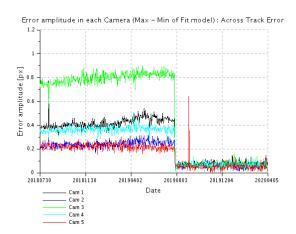
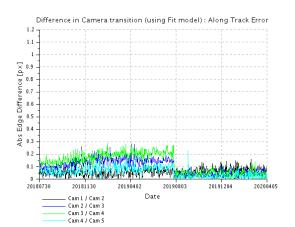


Figure 62: OLCI-A spatial across-track misregistration at each camera transition (left) and maximum amplitude of the across-track error within each camera (left).



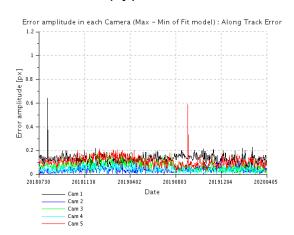


Figure 63: OLCI-A spatial along-track misregistration at each camera transition (left) and maximum amplitude of the along-track error within each camera (left).

2.5.2 OLCI-B

The current Geometric Calibration currently in production is the fourth one, introduced the 30/07/2019. As for OLCI-A, despite compliance to the RMS requirement of 0.5 pixel, OLCI-B showed significant heterogeneity of the performance within the field of view, with discrepancies at camera transitions of up to 1 pixel. Introduction of upgraded IPPVMs greatly improves many performance indicators: the global RMS value decreases form around 0.4 to about 0.3 (Figure 64), the across-track biases decrease significantly for all cameras (Figure 65 to Figure 69) and the field of view homogeneity improves drastically (Figure 70 and Figure 71, but also reduction of the dispersion – distance between the \pm 1 sigma lines – in Figure 65 to Figure 69). It appears however that the instrument pointing is still evolving, in particular for camera 2 (Figure 70) and a new geometric calibration has been done; corresponding ADFs with updated GCMs and IPPVMs have been delivered to PDGS and put in production on 15/04/2020, i.e. the day after the graphs below were generated; their effect will thus be assessed for next Cyclic Report.



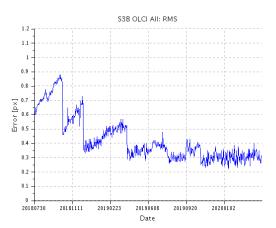
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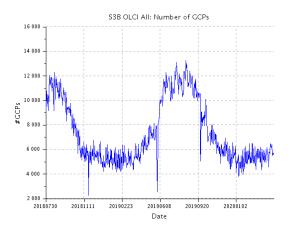
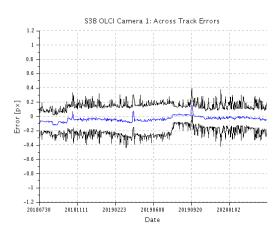


Figure 64: overall OLCI-B georeferencing RMS performance time series over the whole monitoring period (left) and corresponding number of validated control points (right)



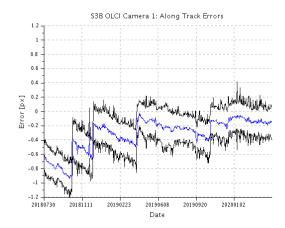
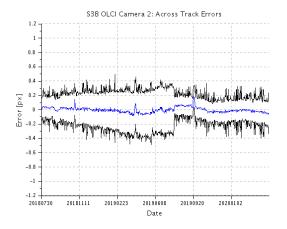


Figure 65: across-track (left) and along-track (right) OLCI-B georeferencing biases time series for Camera 1.



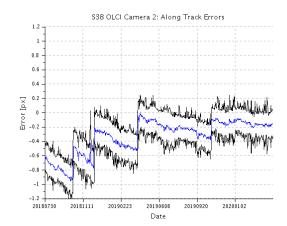


Figure 66: same as Figure 57 for Camera 2.



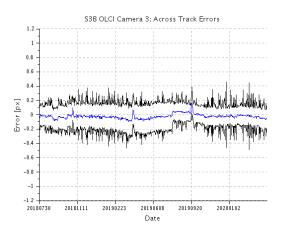
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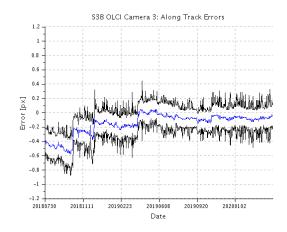
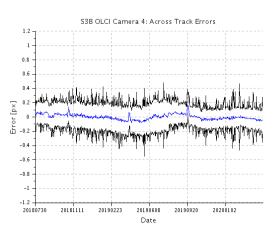


Figure 67: same as Figure 57 for Camera 3.



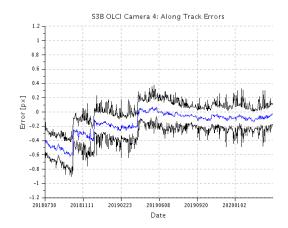
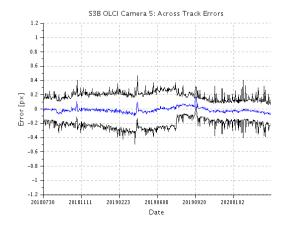


Figure 68: same as Figure 57 for Camera 4.



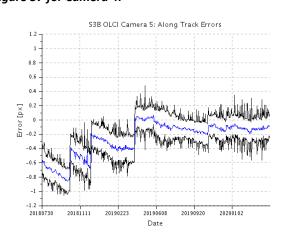


Figure 69: same as Figure 57 for Camera 5.

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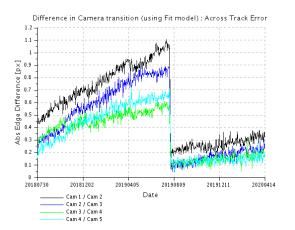
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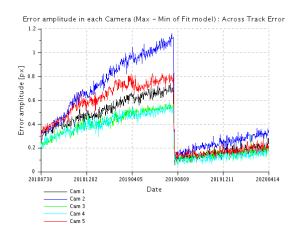
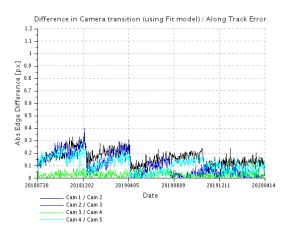


Figure 70: OLCI-B spatial across-track misregistration at each camera transition (left) and maximum amplitude of the across-track error within each camera (left).



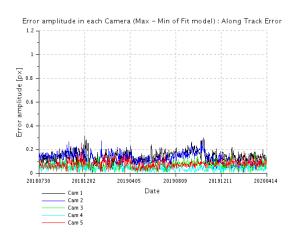


Figure 71: OLCI-B spatial along-track misregistration at each camera transition (left) and maximum amplitude of the along-track error within each camera (left).

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3 OLCI Level 1 Product validation

3.1 [OLCI-L1B-CV-300], [OLCI-L1B-CV-310] - Radiometric Validation

3.1.1 S3ETRAC Service

Activities done

The S3ETRAC service extracts OLCI L1 RR and SLSTR L1 RBT data and computes associated statistics over 49 sites corresponding to different surface types (desert, snow, ocean maximizing Rayleigh signal, ocean maximizing sunglint scattering and deep convective clouds). The S3ETRAC products are used for the assessment and monitoring of the L1 radiometry (optical channels) by the ESLs.

All details about the S3ETRAC/OLCI and S3ETRAC/SLSTR statistics are provided on the S3ETRAC website http://s3etrac.acri.fr/index.php?action=generalstatistics

- Number of OLCI products processed by the S3ETRAC service
- Statistics per type of target (DESERT, SNOW, RAYLEIGH, SUNGLINT and DCC)
- Statistics per sites
- Statistics on the number of records

For illustration, we provide below statistics on the number of S3ETRAC/OLCI records generated per type of targets (DESERT, SNOW, RAYLEIGH, SUNGLINT and DCC) for both OLCI-A (Figure 72) and OLCI-B (Figure 73).

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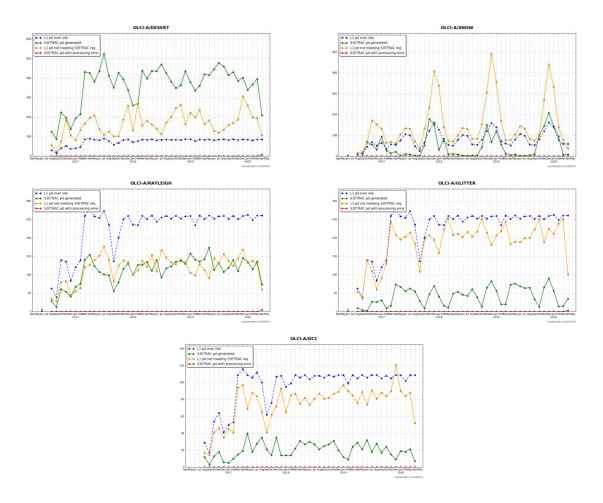


Figure 72: summary of S3ETRAC products generation for OLCI-A

(number of OLCI-A L1 products Ingested, blue – number of S3ETRAC extracted products generated, green – number of S3ETRAC runs without generation of output product (data not meeting selection requirements), yellow – number of runs ending in error, red, one plot per site type).

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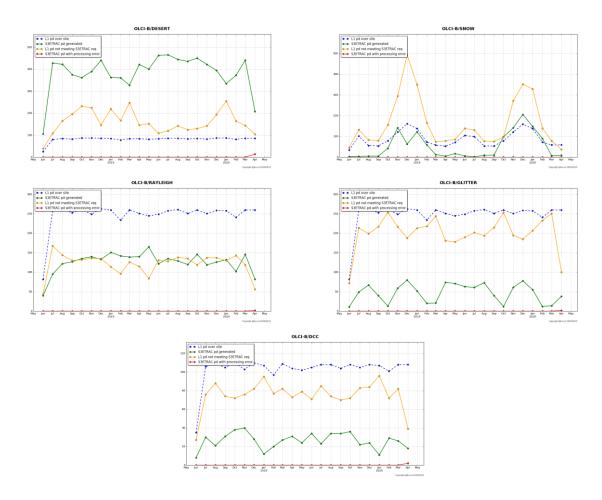


Figure 73: summary of S3ETRAC products generation for OLCI-B

(number of OLCI-B L1 products Ingested, yellow – number of S3ETRAC extracted products generated, blue – number of S3ETRAC runs without generation of output product (data not meeting selection requirements), green – number of runs ending in error, red, one plot per site type).

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3.1.2 Radiometric validation with DIMITRI

Highlights

OLCI-A and OLCI-B L1B radiometry verification as follow:

- The verification is performed until the 17th of April 2020.
- All results from OLCI-A and OLCI-B over Rayleigh, Glint and PICS are consistent with the previous cycle over the used CalVal sites.
- Good stability of both sensors OLCI-A and OLCI-B could be observed, nevertheless the timeseries average shows higher reflectance from OLCI-A.
- Bands with high gaseous absorption are excluded.

Verification and Validation over PICS

- The ingestion of all the available L1B-LN1-NT products from OLCI-A and OLCI-B over the 6 desert calval-sites (Algeria3 & 5, Libya 1 & 4 and Mauritania 1 & 2) has been performed until the 17th of April 2020.
- 2. The results are consistent overall the six used PICS sites (Figure 74 and Figure 75). Both sensors show a good stability over the analyzed period.
- 3. The temporal average over the period **January 2020 Present** of the elementary ratios (observed reflectance to the simulated one) for **OLCI-A** shows gain values between 2-4% over all the VNIR bands (Figure 76). Unlikely, the temporal average over the same period of the elementary ratios for **OLCI-B** shows gain values within 2% (mission requirements) over the VNIR spectral range (Figure 76). The spectral bands with significant absorption from water vapor and O₂ (Oa11, Oa13, Oa14, Oa15 and Oa20) are excluded.

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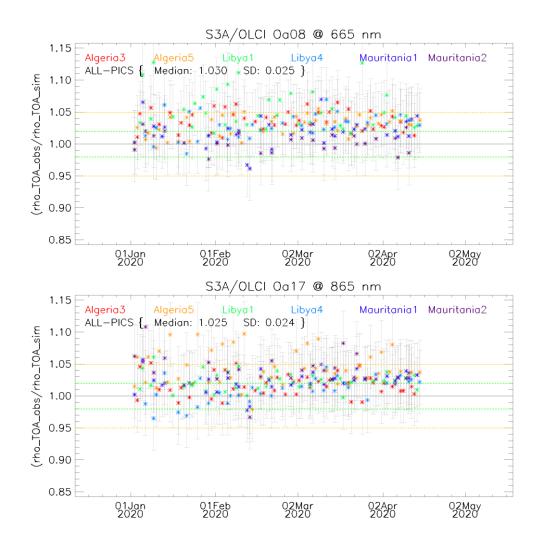


Figure 74: Time-series of the elementary ratios (observed/simulated) signal from OLCI-A for (top to bottom) bands Oa08 and Oa17 respectively over January 2020-Present from the six PICS Cal/Val sites. Dashed-green and orange lines indicate the 2% and 5% respectively. Error bars indicate the desert methodology uncertainty.

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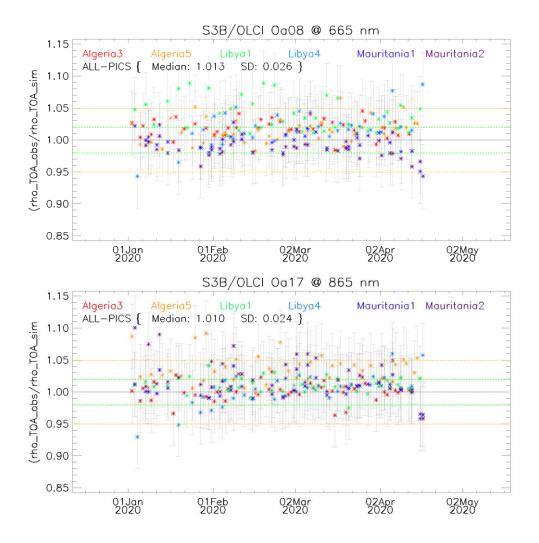


Figure 75: Time-series of the elementary ratios (observed/simulated) signal from OLCI-B for (top to bottom) bands Oa08 and Oa17 respectively over January 2020-Present from the six PICS Cal/Val sites. Dashed-green and orange lines indicate the 2% and 5% respectively. Error bars indicate the desert methodology uncertainty.

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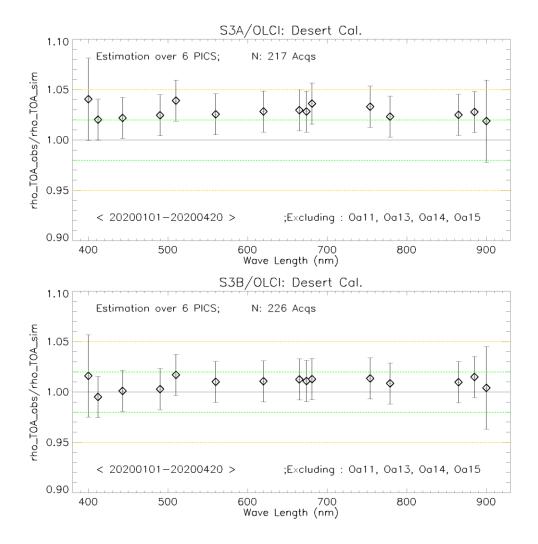


Figure 76: The estimated gain values for OLCI-A and OLCI-B over the 6 PICS sites identified by CEOS over the period January 2020-Present as a function of wavelength. Dashed-green and orange lines indicate the 2% and 5% respectively. Error bars indicate the desert methodology uncertainty.

Cross-mission Intercomparison over PICS:

X-mission Intercomparison with MODIS-A and MSI-A has been performed until February 2019 and February 2020 respectively. Figure 77 shows time-series of the elementary ratios from S2A/MSI, Aqua/MODIS, S3A/OLCI and S3B/OLCI over LYBIA4 sites over the period April 2016 until February 2019 and February 2020 respectively.

We observe a clear stability over the three sensors, associated with higher reflectance from OLCI-A wrt to MSI-A and MODISA. MODISA shows higher fluctuation wrt to MSI-A and OLCI-A/B ones.

Figure 78 shows the time averages of estimated gains for the same sensors (MSI-A, OLCI-A, OLCI-B and MODIS-A) over PICS. The spectral bands with significant absorption from water vapour and O2 are excluded. OLCI-A seems to have higher gain wrt the other sensors, which means that OLCI-A has brighter reflectance than its simulated one by PICS method.

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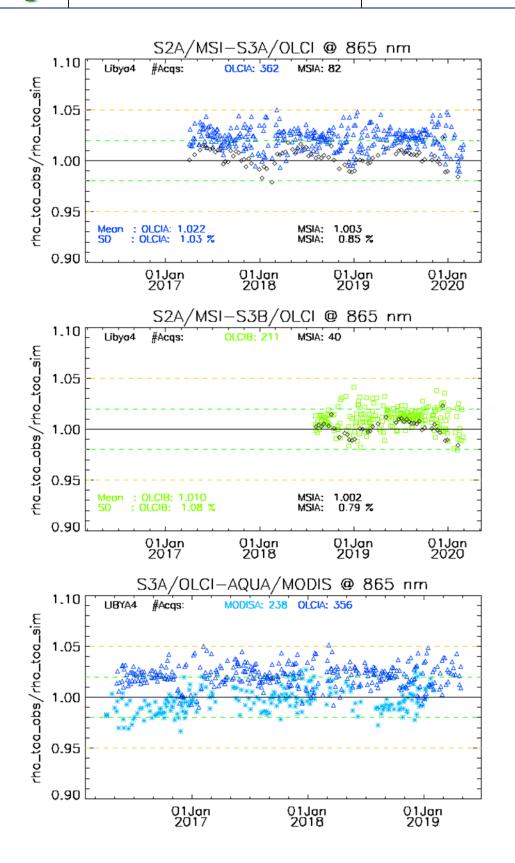
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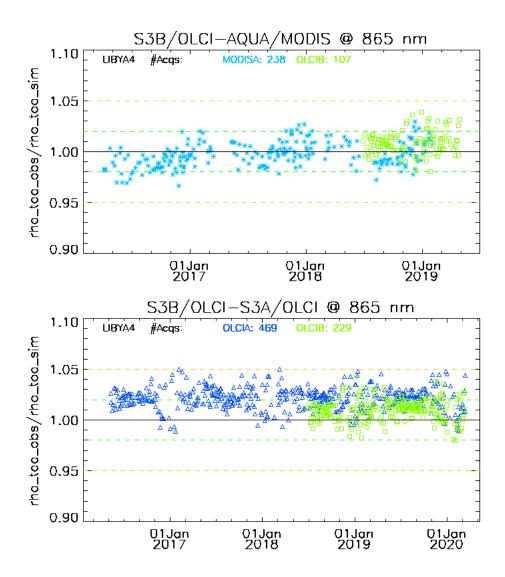


Figure 77: Time-series of the elementary ratios (observed/simulated) signal from (black) S2A/MSI, (blue) S3A/OLCI, (green) S3B/OLCI and (Cyan) Aqua/MODIS for NIR band 865nm over LIBYA4 site. Dashed-green and orange lines indicate the 2% and 5% respectively. The systematic and total uncertainties of the desert methodology are 1% and 5% respectively.

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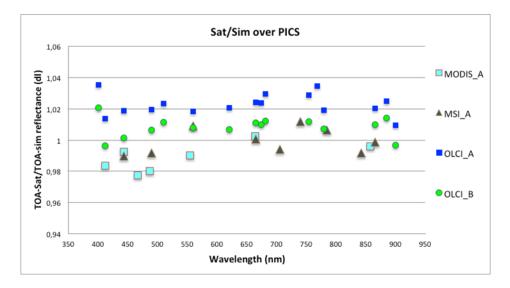


Figure 78: Ratio of observed TOA reflectance to simulated one for (green) S2A/MSI, (purple) S2B/MSI, (red)
Aqua/MODIS, (blue) S3A/OLCI and (dark-green) S3B/OLCI averaged over the six PICS test sites as a function of wavelength.

Validation over Rayleigh

Rayleigh method has been performed over the available mini-files on the Opt-server from missions start to Present from OLCI-A and OLCI-B. The results produced with the configuration (ROI-AVERAGE). The gain coefficients of OLCI-A are consistent with the previous results. Bands Oa01-Oa05 display biases values between 5%-7% while bands Oa06-Oa09 exhibit biases between 2%-3% higher than the 2% mission requirements (Figure 79). The gain coefficients of OLCI-B are lower than OLCI-A ones, where bands Oa01-Oa05 display biases values about 3-5%, when bands Oa6-Oa9 exhibit biases better than 2% mission requirements (Figure 79).

Validation over Glint and synthesis

Glint calibration method with the configuration (ROI-PIXEL) has been performed over the period missions start-present from OLCI-A and OLCI-B. The outcome of this analysis shows a good consistency with the desert and Rayleigh outputs over the NIR spectral range Oa06-Oa09 for both sensors. Glint results from OLCI-A show that the NIR bands are within the 2% (mission requirements), except Oa21 which shows higher biases more than ~5% for both sensors (see Figure 79). Again, the glint gain from OLCI-B looks slightly lower than OLCI-A one.

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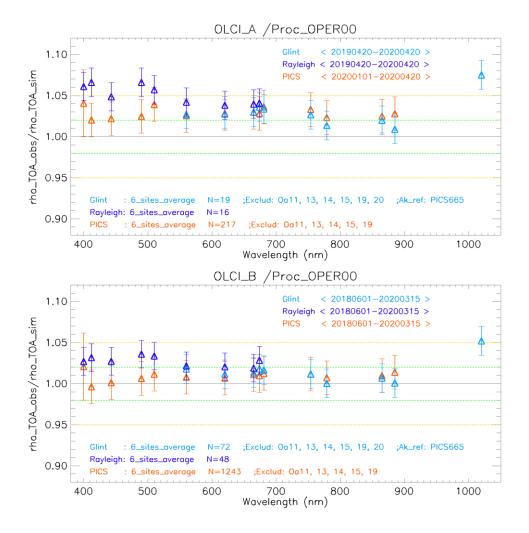


Figure 79: The estimated gain values for OLCI-A and OLCI-B from Glint, Rayleigh and PICS methods over the period missions start-Present as a function of wavelength. We use the gain value of Oa8 from PICS-Desert method as reference gain for Glint method. Dashed-green and orange lines indicate the 2% and 5% respectively.

Error bars indicate the method uncertainties.

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3.1.3 Radiometric validation with OSCAR

The OSCAR Rayleigh method has been applied to the S3A and S3B S3ETRAC data from the 6 oceanic calibration sites listed in Table 3, until March 2020.

Table 3. S3ETRAC Ocean Calibration sites

Site Name	Ocean	North Latitude	South Latitude	East Longitude	West Longitude
PacSE	South-East of Pacific	-20.7	-44.9	-89	-130.2
PacNW	North-West of Pacific	22.7	10	165.6	139.5
PacN	North of Pacific	23.5	15	200.6	179.4
AtlN	North of Atlantic	27	17	-44.2	-62.5
AtIS	South of Atlantic	-9.9	-19.9	-11	-32.3
IndS	South of Indian	-21.2	-29.9	100.1	89.5

In Figure 80 and Table 4 the average OSCAR OLCI-A and OLCI-B Rayleigh results are given for all the processed S3ETRAC data files until march 2020; in Figure 81 only the results for March 2020 are plotted. OLCI-A is about 2 % brighter than OLCIB in blue bands.

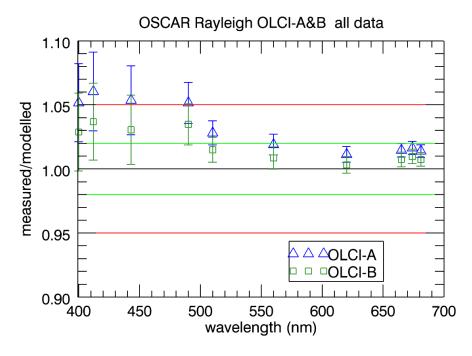


Figure 80. OSCAR Rayleigh S3A and S3B Calibration results as a function of wavelength. Average and standard deviation over all processed S3ETRAC data (for OLCIA 1003 scenes are considered, for OLCI-B 689 scenes)

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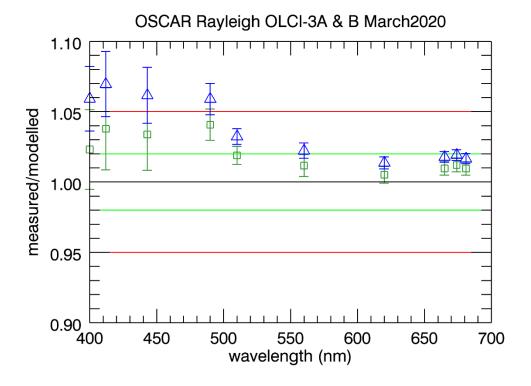


Figure 81. OSCAR Rayleigh S3A and S3B Calibration results as a function of wavelength. Average and standard deviation over processed S3ETRAC data from March 2020 (for OLCI-A 15 scenes are considered, for OLCI-B 31 scenes)

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Table 4. OSCAR Rayleigh calibration results for S3A and S3B (average and standard deviation over all acquisitions) and observed difference (in %) between OLCIA and OLCIB

OLCI band	Wavelength	Oscar Rayleigh OLCIA		Oscar Rayleigh OLCIB	% difference OLCIA	
	(nm)	avg	stdev	avg	stdev	and OLCIB
Oa01	400	1.052	0.030	1.029	0.030	2.16%
Oa02	412	1.060	0.031	1.037	0.030	2.22%
Oa03	443	1.054	0.027	1.031	0.027	2.19%
Oa04	490	1.052	0.016	1.035	0.016	1.60%
Oa05	510	1.028	0.009	1.015	0.010	1.28%
Oa06	560	1.019	0.008	1.009	0.009	1.03%
Oa07	620	1.011	0.006	1.003	0.007	0.81%
Oa08	665	1.015	0.005	1.007	0.006	0.70%
Oa09	674	1.016	0.005	1.010	0.006	0.66%
Oa10	681	1.014	0.005	1.007	0.005	0.64%
Oa11	709	0.996	0.008	0.993	0.008	0.30%
Oa12	754	1.010	0.002	1.009	0.002	0.14%

3.2 [OLCI-L1B-CV-320] - Radiometric Validation with Level 3 products

3.2.1 OLCI-A

There has been no new result during the cycle. Last figures (cycle 20) are considered valid.

3.2.2 OLCI-B

This activity has not started for OLCI-B.

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4 Level 2 Land products validation

4.1 [OLCI-L2LRF-CV-300]

4.1.1 Routine extractions

4.1.1.1 OLCI-A

- The focus for this time period has been on the rolling archive Non Time Critical (NT) data until the 15th of April 2020. More data available for statistical analysis as a concatenation procedure for all available data in the MERMAID processing has been implemented.
- Concatenated time series of OLCI Global Vegetation Index and OLCI Terrestrial Chlorophyll Index have been regenerated on the current rolling archive availability including previous extractions since June 2016 and April 2018 for S3A and S3B respectively.

Figure 82: DeGeb time series over current report period

to Figure 91 below present the Core Land Sites OLCI-A time series over the current period.

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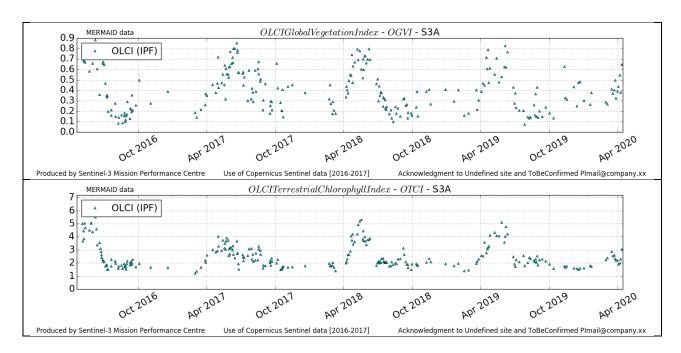


Figure 82: DeGeb time series over current report period

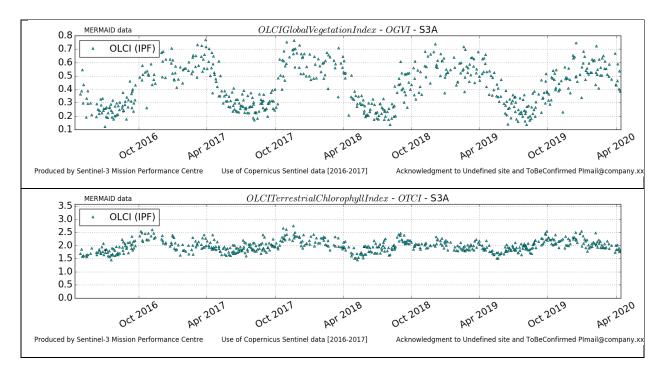


Figure 83: ITCat time series over current report period

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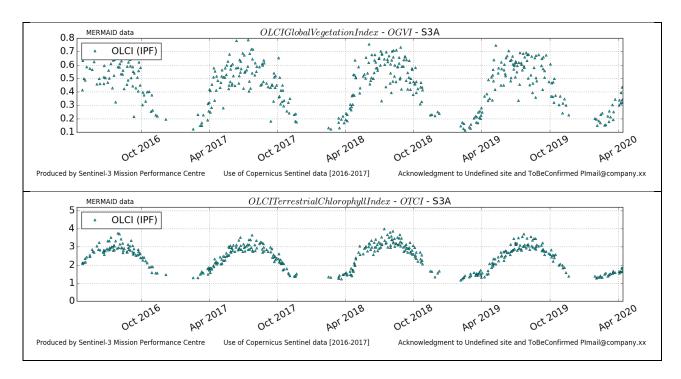


Figure 84: ITsp time series over current report period

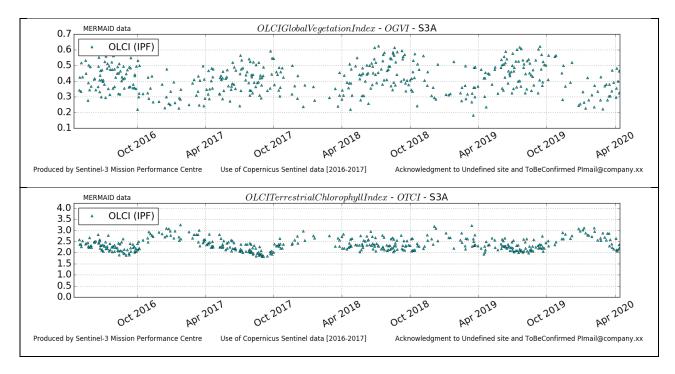


Figure 85: ITSro time series over current report period

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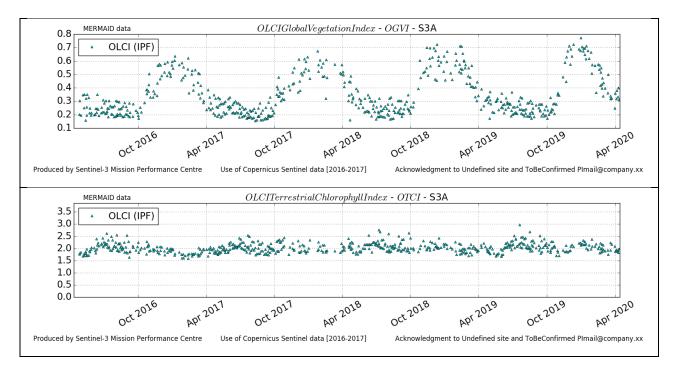


Figure 86: ITTra time series over current report period

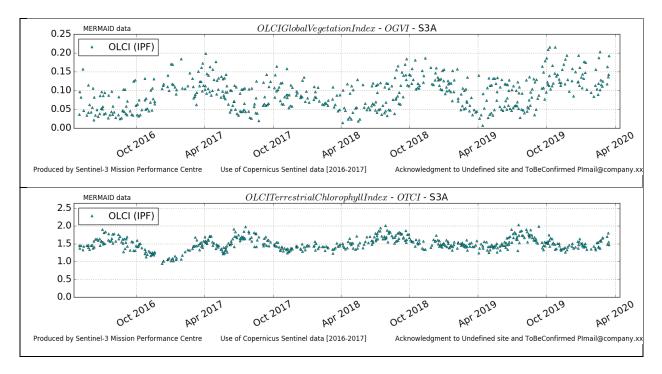


Figure 87: SPAli time series over current report period

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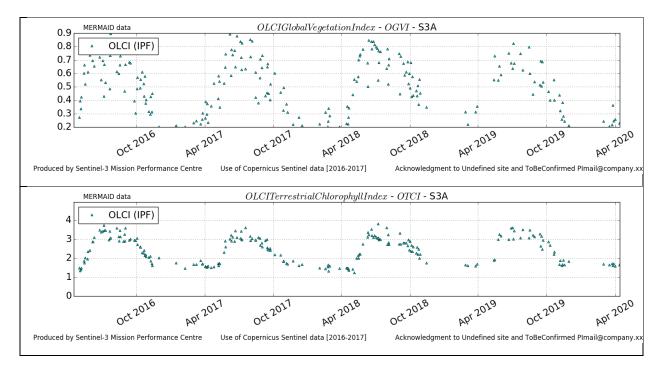


Figure 88: UKNFo time series over current report period

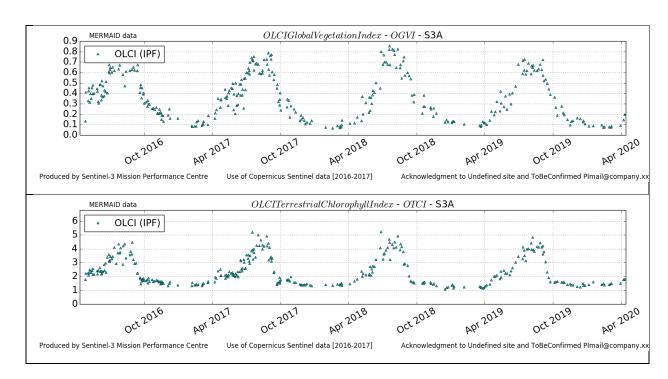


Figure 89: USNe1 time series over current report period

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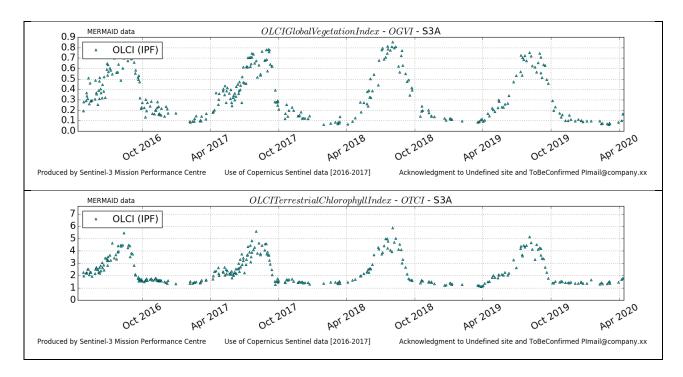


Figure 90: USNe2 time series over current report period

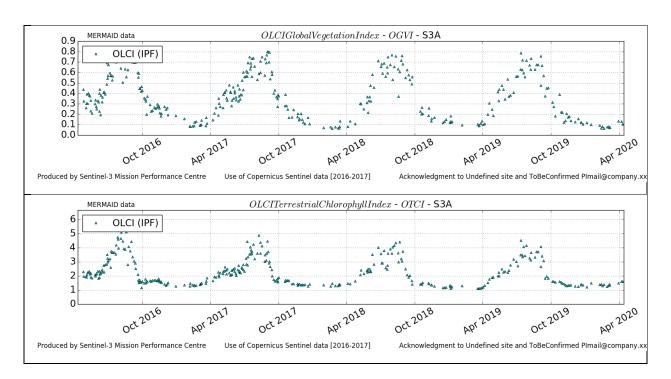


Figure 91: USNe3 time series over current report period

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4.1.1.2 OLCI-B

Figure 92 to Figure 101 below present the Core Land Sites OLCI-B time series over the current period.

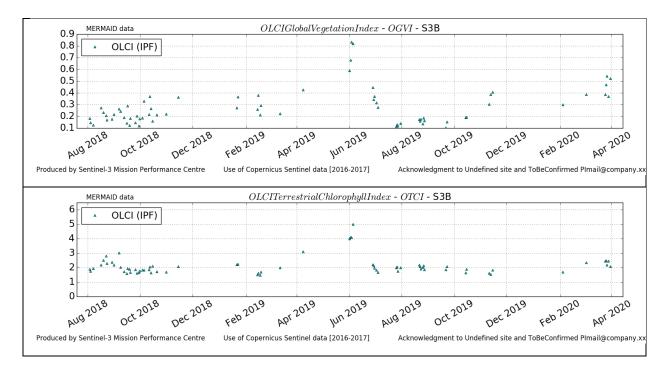


Figure 92: DeGeb time series over current report period

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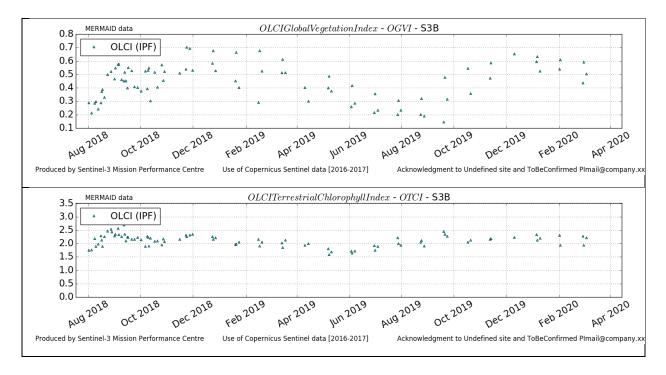


Figure 93: ITCat time series over current report period

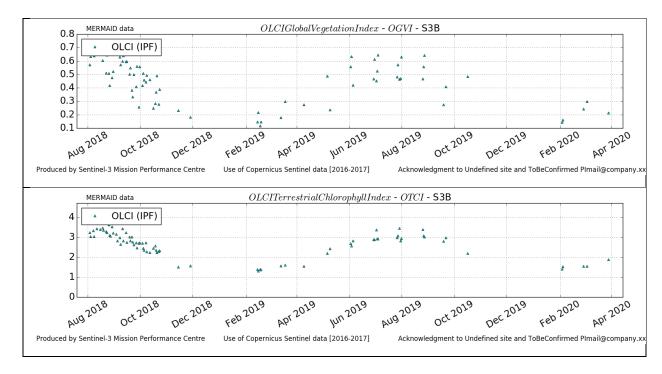


Figure 94: ITsp time series over current report period

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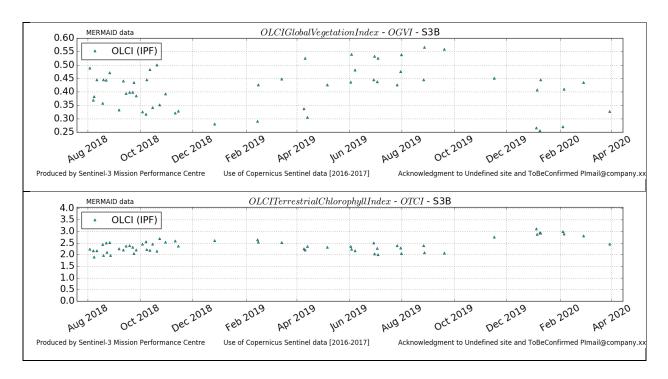


Figure 95: ITSro time series over current report period

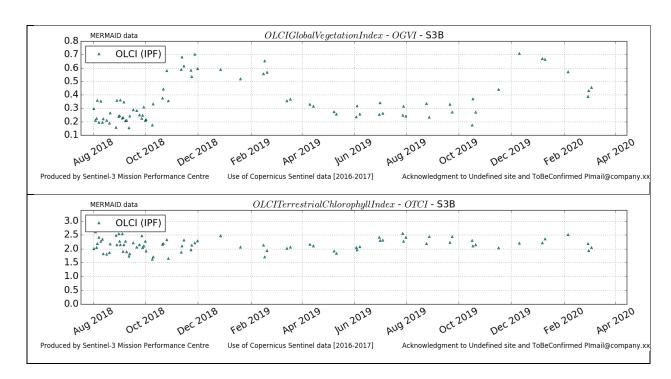


Figure 96: ITTra time series over current report period

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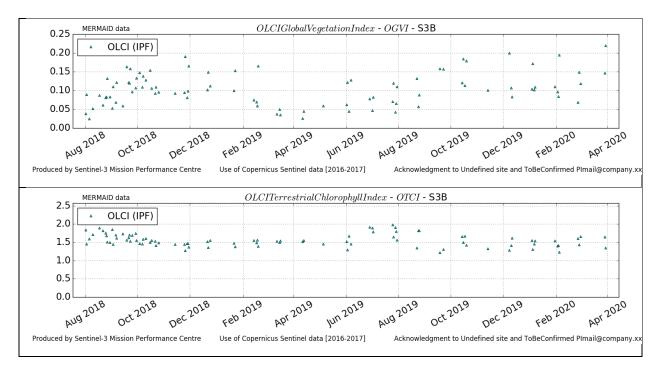


Figure 97: SPAli time series over current report period

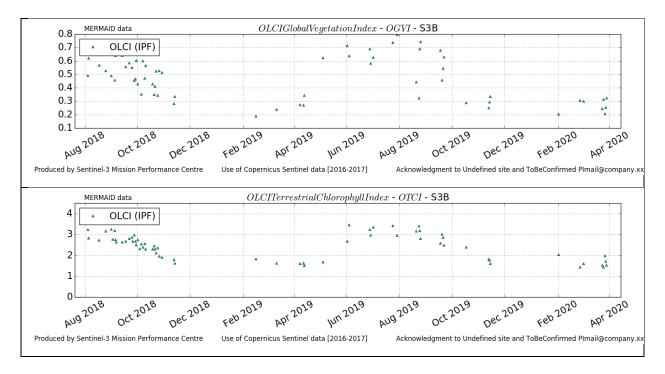


Figure 98: UKNFo time series over current report period

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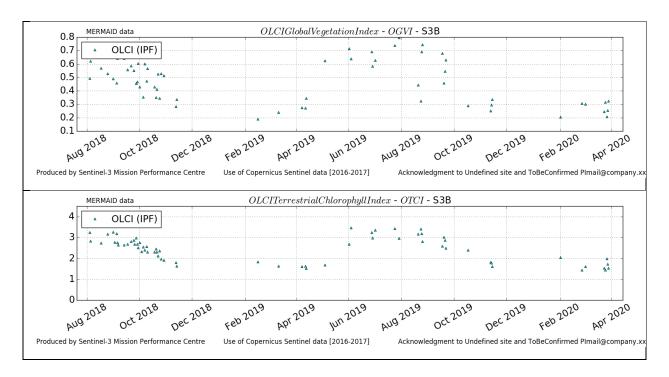


Figure 99: USNe1 time series over current report period

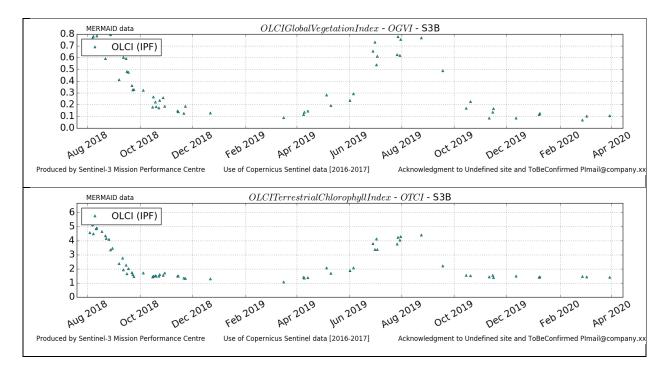


Figure 100: USNe2 time series over current report period

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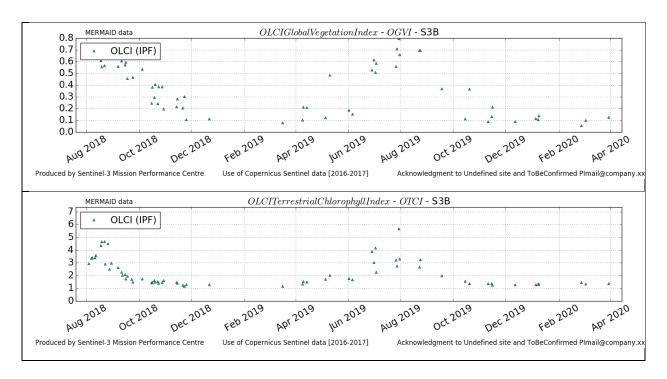


Figure 101: USNe3 time series over current report period

4.1.2 Comparisons with MERIS MGVI and MTCI climatology

Assessment

This report presents the assessment of OLCI data for Chlorophyll Index and Green Vegetation Index collected between 09 March 2020 and 05 April 2020. The OLCI Chlorophyll Index (OTCI) is linearly related to the canopy chlorophyll content (CCC) whereas the OLCI Green Vegetation Index (OGVI) is associated to the Fraction of Absorbed Photosynthetic Active Radiation or FAPAR (an Essential Climate Variable). Indirect verification of the OLCI products is conducted by comparing them to the MERIS archive or climatology. Three by three pixel extractions were collected over ESA Core and CEOS LPV validation sites (Table 5) and comparison statistics are computed (Table 6); such as R², Normalised Root Mean Square Difference (NRMSD) and mean difference or Bias. For consistency, the report shows results for sites that had 12 months of data for both, MERIS and OLCI. For S3A, with some exceptions, the majority of sites present high agreement (R²>8.0) and accuracy (NRMSD<0.1) and absolute bias <0.2 (Table 6). Sites that show lower R² for OTCI (e.g. AU-Calperun, NE-Loboos and US-Moab-Site) are characterised by subtle seasonality and inter-annual variations. However, in these sites NRMSD remains low <0.05 (i.e. high accuracy). A site that stands out by its low R² for OGVI is SP-Ali. This site is characterised by canopies arranged in rows with gaps between rows. For S3B it may be early to draw robust conclusions as it reached its final orbit at the end of 2018 (November 23). However, the results for S3B are reasonable, showing mean R²=0.71 and mean NRMSD=0.07 for OTCl and mean R²=0.62 and mean NRMSD=0.19 for OGVI. Figure 102 to Figure 104 illustrate the agreement of the products for three representative sites: FR-Montiers (DBF), IT-Lison (Cultivated) and BR-Mata-Seca (Non-forest). The sites in the northern hemisphere (FR-Montiers and IT-Lison) depict the beginning of the growing season, whereas the site in

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Brazil (BR-Mata-Seca) is moving towards the end of the growing season. OTCI and OGVI acquisitions for cycle 56 are in accordance with the seasonal trend and within \pm SD of the climatology. Finally, when all sites are pooled together (Figure 105), agreement between MERIS and OLCI is high for both land products (R²~9), NRMSD <0.1 for OTCI and NRMSD <0.2 for OGVI. Slight positive bias is noticed for OGVI (0.063) and marginal negative bias is observed for OTCI (0.015).

Table 5: Validation sites analysed in report S3A 56/S3B 37. Land cover data from GLC2000: shrub and herbaceous (Non-forest), broad-leaved evergreen (EBF), broad-leaved deciduous (DBF), evergreen needle-leaved (ENF), cropland, cultivated and managed areas (Cultivated).

Acronym	Country	Network	Lat	Lon	Land cover
AU-Calperum	Australia	TERN-SuperSites, AusCover/OzFlux	-34.003	140.588	Non-forest
AU-Cape-Tribulation	Australia	TERN-SuperSites, OzFlux	-16.106	145.378	EBF
AU-Cumberland	Australia	TERN-SuperSites, AusCover/OzFlux	-33.615	150.723	EBF
AU-Great-Western	Australia	TERN-SuperSites, AusCover/OzFlux	-30.192	120.654	DBF
AU-Litchfield	Australia	TERN-SuperSites, AusCover/OzFlux	-13.180	130.790	EBF
AU-Robson-Creek	Australia	TERN-SuperSites, AusCover/OzFlux	-17.117	145.630	EBF
AU-Rushworth	Australia	TERN-AusCover	-36.753	144.966	DBF
AU-Tumbarumba	Australia	TERN-SuperSites, AusCover/OzFlux	-35.657	148.152	EBF
AU-Warra-Tall	Australia	TERN-SuperSites, AusCover/OzFlux	-43.095	146.654	EBF
AU-Watts-Creek	Australia	TERN-AusCover	-37.689	145.685	EBF
AU-Wombat	Australia	TERN-SuperSites, AusCover/OzFlux	-37.422	144.094	EBF
BR-Mata-Seca	Brazil	ENVIRONET	-14.880	-43.973	Non-forest
CR-Santa-Rosa	Costa Rica	ENVIRONET	10.842	-85.616	EBF
DE-Geb	Deutschland	CORE	51.100	10.914	Cultivated
DE-Selhausen	Deutschland	ICOS	50.866	6.447	Cultivated
FR-Aurade	France	ICOS	43.550	1.106	Cultivated
FR-Estrees-Mons	France	ICOS Associated	49.872	3.021	Cultivated
FR-Guayaflux	France	ICOS Associated	5.279	-52.925	EBF
FR-Montiers	France	ICOS	48.538	5.312	DBF
FR-Puechabon	France	ICOS	43.741	3.596	ENF
IT-Cat	Italy	CORE	37.279	14.883	Cultivated
IT-Collelongo	Italy	EFDC	41.849	13.588	DBF
IT-Lison	Italy	ICOS	45.740	12.750	Cultivated
IT-Tra	Italy	CORE	37.646	12.867	Cultivated
NE-Loobos	Netherlands	ICOS Associated	52.166	5.744	ENF
SE-Dahra	Senegal	KIT / UC	15.400	-15.430	Cultivated
SP-Ali	Spain	CORE	38.452	-1.065	Cultivated
UK-NFo	United Kingdom	CORE	50.845	-1.540	DBF
UK-Wytham-Woods	United Kingdom	ForestGeo - NPL	51.774	-1.338	DBF
US-Bartlett	United States	NEON, AERONET	44.064	-71.287	DBF
US-Central-Plains	United States	NEON, AERONET	40.816	-104.746	Non-forest
US-Harvard	United States	NEON, AERONET	42.537	-72.173	DBF
US-Moab-Site	United States	NEON, AERONET	38.248	-109.388	Non-forest
US-Mountain-Lake	United States	NEON, AERONET	37.378	-80.525	DBF
US-Oak-Rige	United States	NEON, AERONET	35.964	-84.283	DBF
US-Talladega	United States	NEON, AERONET	32.950	-87.393	ENF

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Table 6: Comparison statistics between monthly S3A/B OLCI land products and MERIS archive data.

					S3A					S3B						
Site Acronym	OTCI vs MTCI			OGVI vs MGVI			OTCI vs MTCI			OGVI vs MGVI						
	n	R2	NRMSD	Bias	n	R2	NRMSD	Bias	n	R2	NRMSD	Bias	n	R2	NRMSD	Bias
AU-Calperum	12	0.48	0.04	0.10	12	0.91	0.08	-0.01	12	0.04	0.05	0.04	12	0.70	0.16	-0.01
AU-Cape-Tribulation	12	0.81	0.05	-0.09	12	0.36	0.06	0.14	11	0.76	0.04	-0.20	11	0.36	0.15	0.10
AU-Cumberland	12	0.93	0.02	0.02	12	0.52	0.07	0.08	12	0.52	0.06	0.02	12	0.48	0.13	0.06
AU-Great-Western	12	0.96	0.02	0.13	12	0.91	0.00	0.04	12	0.90	0.02	0.14	12	0.72	0.10	0.03
AU-Litchfield	12	0.91	0.02	-0.01	12	0.94	0.06	0.03	12	0.62	0.08	0.01	12	0.83	0.09	0.01
AU-Robson-Creek	12	0.92	0.03	-0.06	12	0.86	0.07	0.10	11	0.79	0.05	-0.17	11	0.56	0.11	0.12
AU-Rushworth	12	0.84	0.04	0.20	12	0.49	0.04	0.10	12	0.17	0.09	-0.11	12	0.46	0.08	0.04
AU-Tumbarumba	12	0.81	0.06	0.36	12	0.28	0.10	0.12	12	0.62	0.08	0.19	12	0.30	0.10	0.03
AU-Warra-Tall	12	0.68	0.06	-0.03	12	0.34	0.17	0.05	7	0.52	0.08	-0.31	7	0.19	0.35	0.01
AU-Watts-Creek	12	0.70	0.05	0.10	12	0.20	0.08	0.10	12	0.65	0.06	0.04	12	0.01	0.17	0.07
AU-Wombat	12	0.89	0.04	0.19	12	0.29	0.08	0.09	12	0.63	0.05	-0.09	12	0.03	0.11	0.07
BR-Mata-Seca	12	0.96	0.06	-0.08	12	0.98	0.07	0.00	12	0.97	0.05	-0.10	12	0.98	0.07	0.01
CR-Santa-Rosa	12	0.98	0.04	0.13	12	0.63	0.20	0.12	12	0.84	0.12	-0.04	12	0.38	0.29	0.07
DE-Geb	12	0.86	0.11	-0.09	12	0.88	0.15	0.05	10	0.76	0.11	-0.04	10	0.53	0.26	0.00
DE-Selhausen	12	0.90	0.07	-0.02	12	0.52	0.21	0.07	11	0.68	0.10	-0.15	11	0.11	0.30	0.01
FR-Aurade	12	0.76	0.12	0.08	12	0.80	0.19	0.14	11	0.81	0.11	0.03	11	0.85	0.16	0.09
FR-Estrees-Mons	12	0.94	0.08	0.03	12	0.89	0.11	0.06	12	0.89	0.11	0.14	12	0.89	0.14	0.06
FR-Guayaflux	12	0.68	0.04	-0.16	12	0.21	0.07	0.17	11	0.81	0.03	-0.26	11	0.01	0.22	0.24
FR-Montiers	12	0.99	0.05	-0.12	12	0.98	0.06	0.04	11	0.98	0.06	-0.11	11	0.93	0.15	0.05
FR-Puechabon	12	0.69	0.05	-0.09	12	0.91	0.06	0.09	12	0.87	0.05	0.03	12	0.92	0.06	0.04
IT-Cat	12	0.63	0.04	-0.35	12	0.72	0.16	0.02	12	0.49	0.06	-0.31	12	0.36	0.21	0.03
IT-Collelongo	12	0.97	0.07	-0.02	12	0.98	0.08	0.01	11	0.80	0.23	0.01	11	0.86	0.24	0.01
IT-Lison	12	0.97	0.04	-0.04	12	0.96	0.07	0.08	11	0.90	0.06	-0.07	11	0.92	0.10	0.08
IT-Tra	12	0.79	0.02	-0.05	12	0.96	0.10	0.07	12	0.47	0.05	0.07	12	0.96	0.10	0.09
NE-Loobos	12	0.59	0.09	0.04	12	0.85	0.10	0.04	11	0.57	0.07	0.05	11	0.85	0.10	0.03
SE-Dahra	12	0.60	0.07	-0.03	12	0.80	0.52	-0.01	8	0.04	0.16	-0.08	8	0.71	0.77	0.01
SP-Ali	12	0.92	0.02	0.07	12	0.04	0.28	0.02	12	0.88	0.03	0.11	12	0.01	0.41	0.02
UK-NFo	12	0.98	0.04	-0.25	12	0.97	0.08	0.07	10	0.97	0.04	-0.25	10	0.96	0.11	0.06
UK-Wytham-Woods	12	0.96	0.06	0.07	12	0.98	0.05	0.10	10	0.89	0.09	-0.17	10	0.84	0.16	0.06
US-Bartlett	12	0.95	0.05	0.03	12	0.97	0.10	0.06	11	0.84	0.09	-0.05	11	0.84	0.22	0.02
US-Central-Plains	12	0.73	0.03	-0.06	12	0.90	0.21	0.01	8	0.46	0.06	-0.09	8	0.76	0.31	0.01
US-Harvard	12	0.99	0.02	-0.14	12	0.97	0.09	0.05	11	0.98	0.05	-0.21	11	0.92	0.16	0.02
US-Moab-Site	12	0.60	0.02	0.05	12	0.14	0.22	0.02	11	0.53	0.04	0.01	11	0.06	0.43	0.03
US-Mountain-Lake	12	0.99	0.03	-0.22	12	0.99	0.05	0.04	11	0.97	0.05	-0.52	11	0.98	0.08	0.00
US-Oak-Rige	12	0.99	0.04	-0.06	12	0.98	0.07	0.04	12	0.98	0.06	-0.10	12	0.96	0.09	0.03
US-Talladega	12	0.97	0.02	-0.14	12	0.99	0.05	0.07	12	0.91	0.05	-0.18	12	0.95	0.10	0.07

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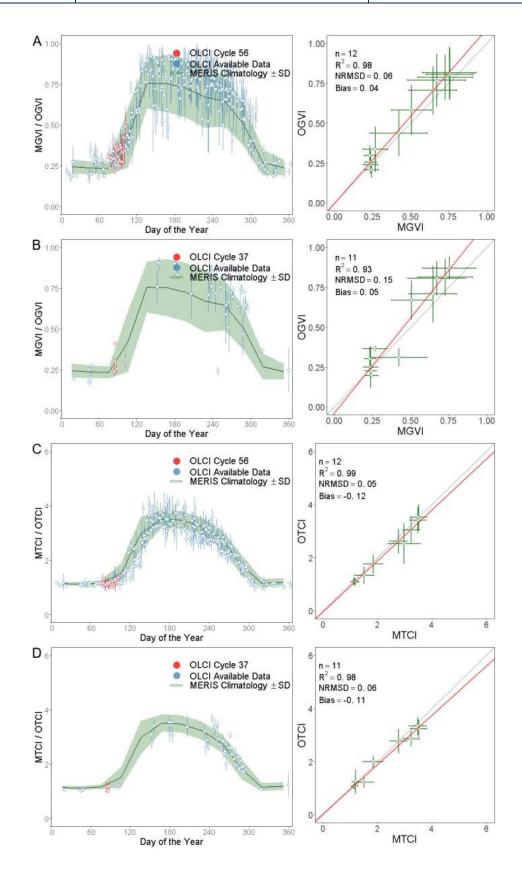


Figure 102: Time-series OGVI and OTCI and corresponding scatterplot of monthly mean for site FR-Montiers, France, land cover Broadleaved, deciduous, closed. A and C represent S3A; B and D represent S3B.

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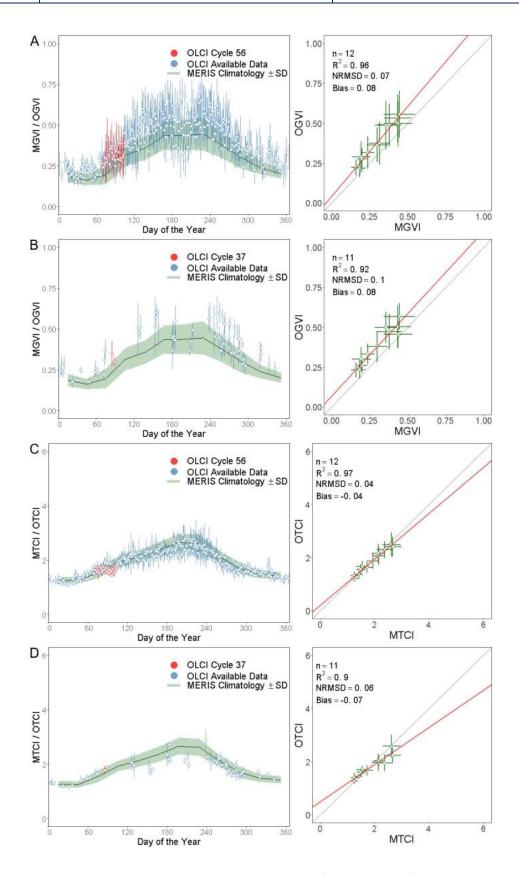


Figure 103: Time-series OGVI and OTCI and corresponding scatterplot of monthly mean for site IT-Lison, Italy, land cover Cropland. A and C represent S3A; B and D represent S3B.

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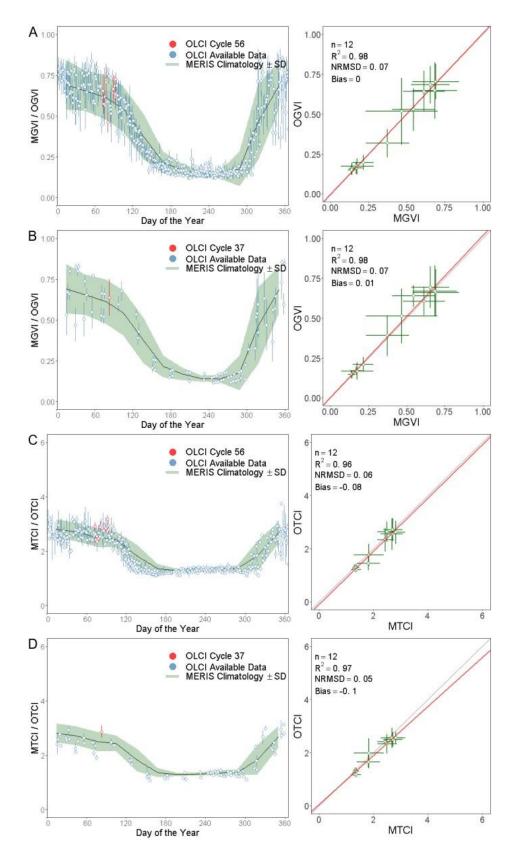


Figure 104: Time-series OGVI and OTCI and corresponding scatterplot of monthly mean for site BR-Mata-Seca, Brazil, land cover Herbaceous, closed-open. A and C represent S3A; B and D represent S3B.

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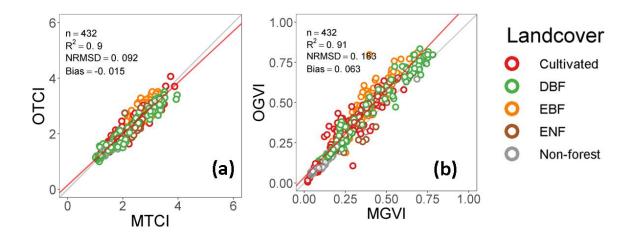


Figure 105: Comparison of OTCI-MTCI (a) and OGVI-MGVI (b). Points in the scatterplot represent the monthly mean of all available S3A and MERIS archive over 36 validation sites. Red and grey lines represent the modelled and 1:1 lines respectively. The scatterplots are updated to include extractions from cycle S3A 56.

4.2 [OLCI-L2LRF-CV-410 & OLCI-L2LRF-CV-420] — Cloud Masking & Surface Classification for Land Products

There has been no new result during the cycle. Last figures (cycle 27) are considered valid.

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5 Level 2 Water products validation

5.1 [OLCI-L2-CV-210, OLCI-L2-CV-220] – Vicarious calibration of the NIR and VIS bands

5.1.1 OLCI-A

There has been no update of the SVC (System Vicarious Calibration) during Cycle 056. Last figures (cycle 17) are considered valid.

5.1.2 OLCI-B

OLCI-B SVC has been reattempted using (a) current OL_2 Marine PB and (b) latest delivered one (PB 1.32-B), including BPC upgrade, as no decision has been taken yet regarding the use of PB 1.32 in operations. Corresponding results are presented below for the two cases. It clearly demonstrates two points:

- 1. SVC is now feasible for OLCI-B and yields good performance on validation
- 2. The BPC upgrade of PB 1.32 is beneficial for the SVC match-up selection (increase of the number of selected calibration match-ups by about 25%) as well as for the validation performance with independent in-situ data.

Results are not further discussed here since there is no decision yet regarding implementation in the Ground Segment.

5.2 [OLCI-L2WLR-CV-300, OLCI-L2WLR-CV-310, OLCI-L2WLR-CV-32, OLCI-L2WLR-CV-330, OLCI-L2WLR-CV-340, OLCI-L2WLR-CV-350, OLCI-L2WLR-CV-360 and OLCI-L2WLR-CV-370] — Level 2 Water-leaving Reflectance product validation.

5.2.1 Acknowledgements

S3-MPC acknowledges all PIs mentioned below and their respective institutions for their valuable contribution to the validation of OLCI L2 water products with a special emphasis on AERONET-OC PIs for their unique contribution to NRT data validation and a special mention to Giuseppe Zibordi maintaining and providing data over 5 ground stations. AERONET-OC is indeed from far the largest contributor of Fiducial Reference Measurements for routine quantitative data validation.

❖ AERONET-OC

- AAOT, Galata, Gloria, GDT, HLH, Irbe Lighthouse: Giuseppe Zibordi, Joint Research Centre of the European Commission
- leodo, Socheongcho: Young-Je Park & Hak-Yeol You, Korean Institute of Ocean Science and Technology & Korea Hydrographic and Oceanographic Administration

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- o LISCO: Sam Ahmed, Alex Gilerson, City College of New York
- MVCO: Hui Feng and Heidi Sosik, Ocean Process Analysis Laboratory (OPAL), Woods Hole
 Oceanographic Institution
- Thornton: Dimitry Van der Zande, RBINS/OD Nature
- Lucinda: Thomas Schroeder, Integrated Marine Observing System, IMOS
- USC_SEAPRISM: Burton Jones and Curtiss Davis, University Southern California | USC, Oregon State University
- WaveCIS: Alan Weidemann, Bill Gibson, Robert Arnone, University of Southern MS, Coastal Studies Inst – LSU, Naval Research Laboratory
- Ariake tower: Joji Ishizaka, Kohei Arai, Nagoya University & Saga University
- Blyth NOAH: Rodney Forster, University of Hull, UK
- Casablanca platform: Giuseppe Zibordi, Marco Talone, Joint Research Centre of the European Commission
- Grizzly bay, Lake Okeechobee, South Greenbay: NimaPahlevan, NASA
- Lake Erie: Tim Moore, Steve Ruberg, Menghua Wang, University of New Hampshire & NOAA

BOUSSOLE

 David Antoine, Enzo Vellucci (Curtin University, Perth & Laboratoire d'Oceanographie de Villefranche, CNRS)

MOBY

Kenneth Voss & Carol Johnson (University of Miami & NIST)

SLGO

 Simon Belanger, Thomas Jaegler & Peter Galbraith (Arctus, Inc & Department of fisheries and Ocean Canada)

AWI

Astrid Bracher (Alfred-Wegener-Institut)

IMOS

Thomas Schroeder (Integrated Marine Observing System, IMOS)

◆ BSH

Holger Klein (Bundesamt für Seeschifffahrt und Hydrographie, BSH)

Proval

Edouard Leymarie (Laboratoire d'Oceanographie de Villefranche, CNRS)

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5.2.2 OLCI-A

Activities done

The focus for this time period has been on the rolling archive Non Time Critical (NT) data until the 17th of April 2020.

- Current reporting period is hereafter compared to the reprocessed archive covering the April 2016 to November 2017 period. No issues are reported neither in the extraction process nor in OLCI data.
- All extractions and statistics have been regenerated on the current rolling archive availability including all the extraction since July 2017. The available matchups therefore represent over almost three years of operation.
- At best 402 and 406 matchups at 490 and 560nm respectively are useful for this time period. OLCI's performances remain nominal.

Overall Water-leaving Reflectance performance

Scatter plots and Performance Statistics

Figure 106 and Figure 107 below present the scatterplots and statistics of OLCI FR versus in situ reflectance. Two time periods are considered:

- The reprocessed archive covering the April 2016 to November 2017 time period
- The current reporting period computed on the NT dataset.

The current reporting period statistics are in line with the reprocessed dataset.

Table 7 below summarises the statistics over the reprocessing period while Table 8 provides the same figures for the NT rolling Archive over July 2017 – present. The latter statistics are almost within the requirements (5% accuracy in the blue/green bands) – as demonstrated by the RPD values between 2 and 4.5%, with the noticeable exception of 412 nm with 8.5%. Performances over the current period appear a bit lower than for the calibration period (except at 412 nm), but of the same order of magnitude.

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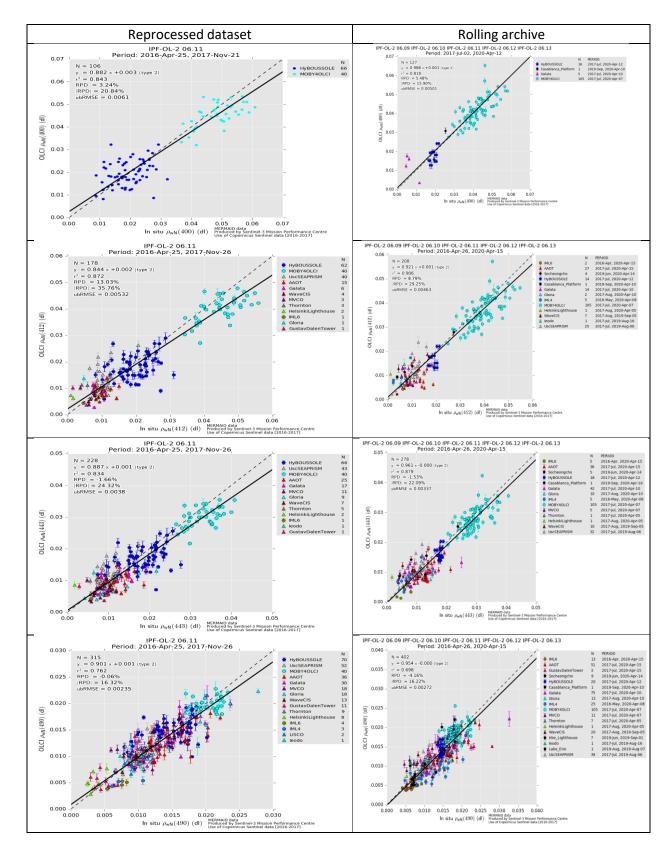


Figure 106: Scatter plots of OLCI-A versus in situ radiometry (FR data). Reprocessed dataset (left), all available data for the current time period (right), Oa1 to Oa4 (400 to 490 nm)

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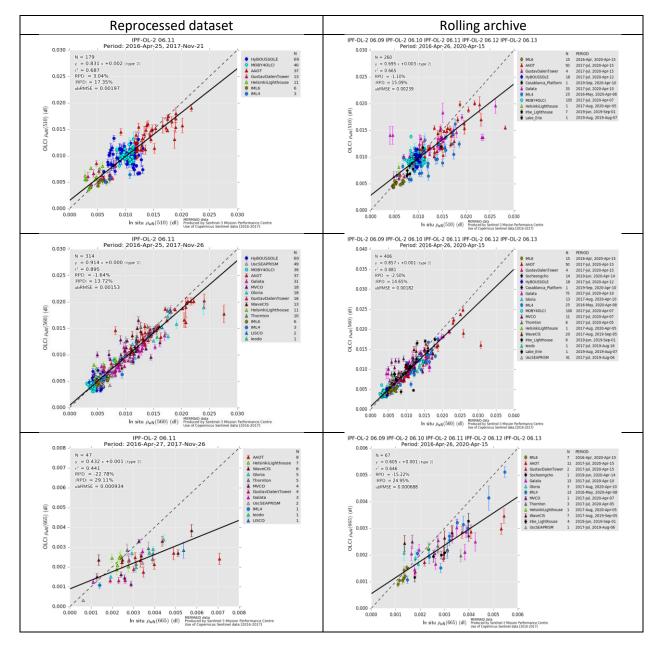


Figure 107: Scatter plots of OLCI-A versus in situ radiometry (FR data). Reprocessed dataset (left), all available data for the current time period (right), Oa5 Oa6 and Oa8 (510, 560 and 665 nm).

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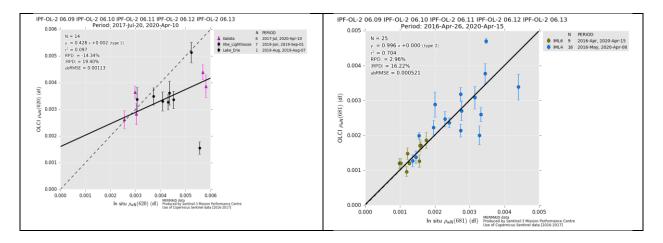


Figure 108: Scatter plots of OLCI-A versus in situ radiometry (FR data) at two additional wavelengths (620 and 681 nm, Oa7 and Oa10) for the current time period, thanks to enhanced capacities of some AERONET-OC platforms and of IML buoys. There is no equivalent for the reprocessed dataset.

Table 7: OLCI-A FR statistics over REP 006 period; FR data.

rable 7. Ozer ATR Statistics over REI _ ooo periou, TR aata.									
lambda	N	RPD	RPD	MAD	RMSE	slope	intercept r	2	
400	105	3.52%	20.74%	-0.0009	0.0062	0.8774	0.0029	0.8435	
412	178	13.03%	35.76%	-0.0011	0.0054	0.8444	0.0021	0.8721	
443	228	-1.66%	24.32%	-0.0013	0.0040	0.8874	0.0006	0.8336	
490	315	-0.06%	16.32%	-0.0004	0.0024	0.9009	0.0009	0.7618	
510	179	3.04%	17.35%	-0.0002	0.0020	0.8314	0.0015	0.6869	
560	314	-1.64%	13.72%	-0.0003	0.0016	0.9139	0.0004	0.8946	
665	47	-22.78%	29.11%	-0.0009	0.0013	0.4325	0.0009	0.4406	

Table 8: OLCI-A FR statistics over July 2017-present.

lambda	N	RPD	RPD	MAD	RMSE	slope	intercept	r2	
400	127	5.48%	15.90%	0.000	0.005	0.988	0.001		0.82
412	208	8.79%	29.25%	-0.001	0.005	0.921	0.001		0.91
443	278	-1.53%	22.09%	-0.001	0.004	0.961	0.000		0.88
490	402	-4.16%	16.22%	-0.001	0.003	0.954	0.000		0.70
510	260	-1.10%	15.09%	-0.001	0.002	0.695	0.003		0.66
560	406	-2.50%	14.65%	-0.001	0.002	0.857	0.001		0.88
620	14	-14.34%	19.40%	-0.001	0.001	0.428	0.002		0.10
665	67	-15.22%	24.95%	-0.001	0.001	0.605	0.001		0.65
681	25	2.96%	16.22%	0.000	0.001	0.996	0.000		0.70

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Time series

Figure 109 and Figure 110 below present Galata and AAOT in situ and OLCI time series over the June 2017-present period, for the same IPF configuration (from a scientific point of view).

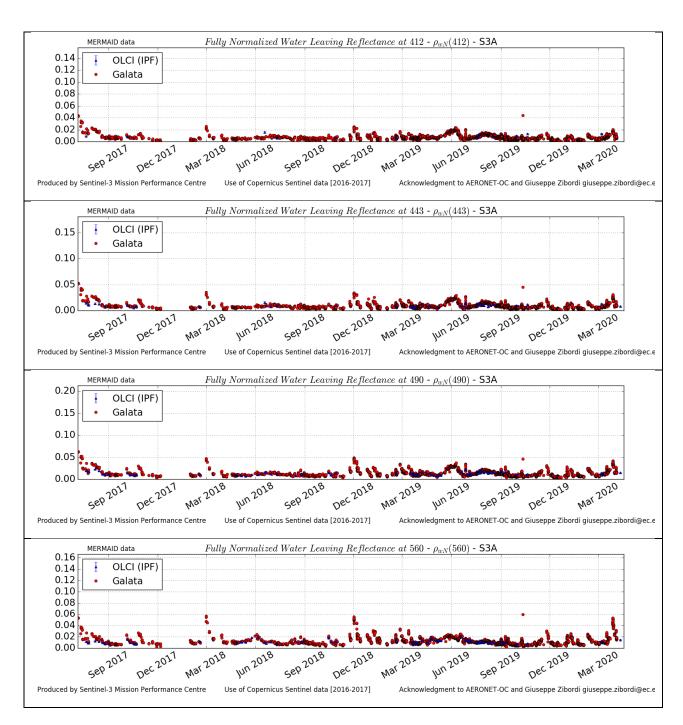


Figure 109: Galata time series over current report period

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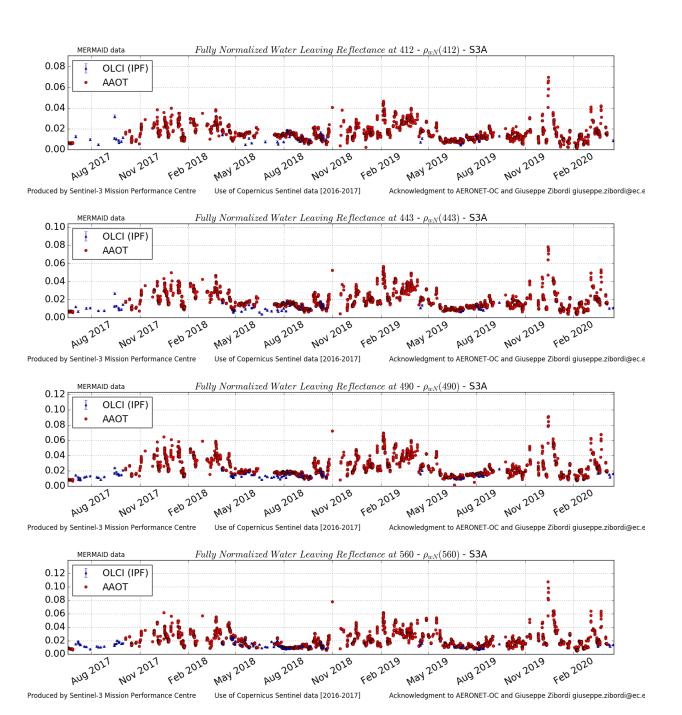


Figure 110: AAOT time series over current report period

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5.2.3 OLCI-B

Activities done

- The focus for this time period has been on the rolling archive Non Time Critical (NT) data until the 20th of March 2020.
- All extractions and statistics have been regenerated on the current rolling archive availability including all the extraction since February 2019.
- At best 202 and 220 matchups at 490 and 560nm respectively are useful for this time period.

It must be noted that OLCI-B has no SVC adjustment and as such cannot be expected to provide performances of the same level of quality than OLCI-A.

Overall Water-leaving Reflectance performance

Scatter plots and Performance Statistics

- Figure 111 below presents the scatterplots and statistics of OLCI-B FR versus in situ reflectance.
- ❖ Table 9 below summarises the statistics over the current reporting period.

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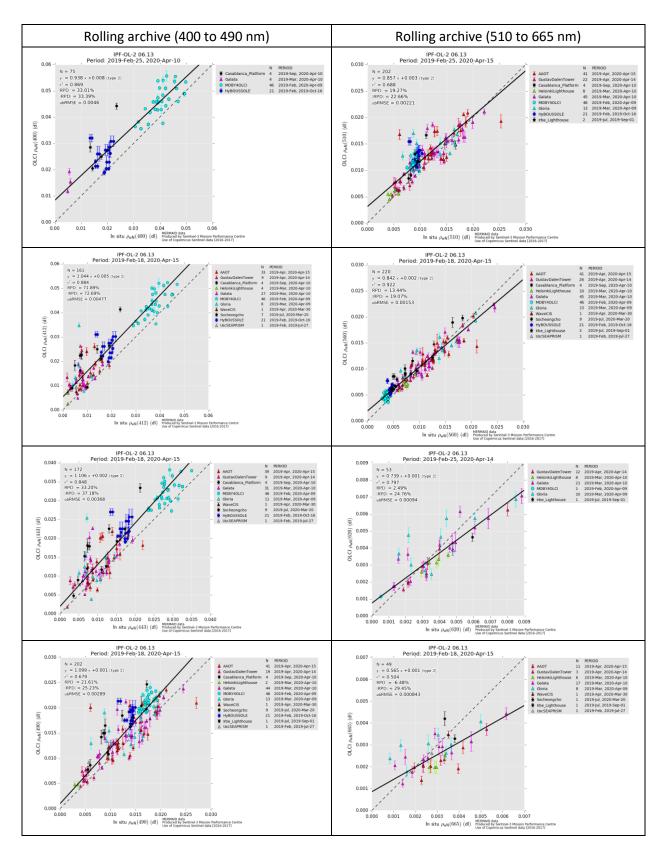


Figure 111: Scatter plots of OLCI-B versus in situ radiometry (FR data). All available data for the current time period.

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Table 9: OLCI-B FR statistics over February 2019 to Present.

lambda	N	RPD	RPD	MAD	RMSE	slope	intercept	r2	
400	80	33.01%	33.39%	0.007	0.009	0.873	0.011	0.8	38
412	161	71.89%	72.69%	0.006	0.008	1.044	0.005	0.8	38
443	172	33.20%	37.18%	0.004	0.005	1.106	0.002	0.8	35
490	202	21.61%	25.23%	0.002	0.004	1.099	0.001	0.6	58
510	205	19.27%	22.66%	0.002	0.004	0.803	0.004	0.5	50
560	220	13.44%	19.07%	0.000	0.002	0.842	0.002	0.9	€2
620	60	2.49%	24.76%	0.000	0.002	0.541	0.002	0.4	10
665	49	-6.48%	29.45%	0.000	0.001	0.565	0.001	0.5	50

Time series

Figure 112 and Figure 113 below present AAOT and GALATA in situ and OLCI-B time series over the current period.

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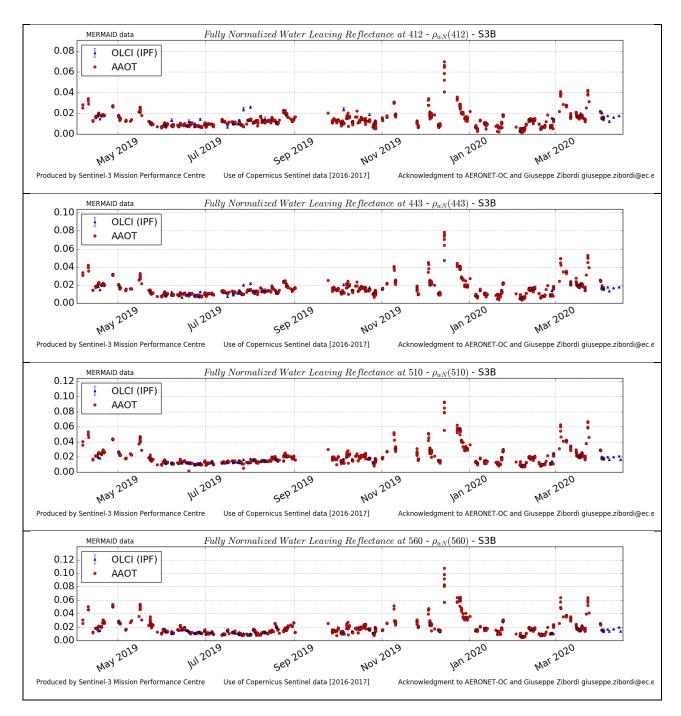


Figure 112: AAOT time series over current report period

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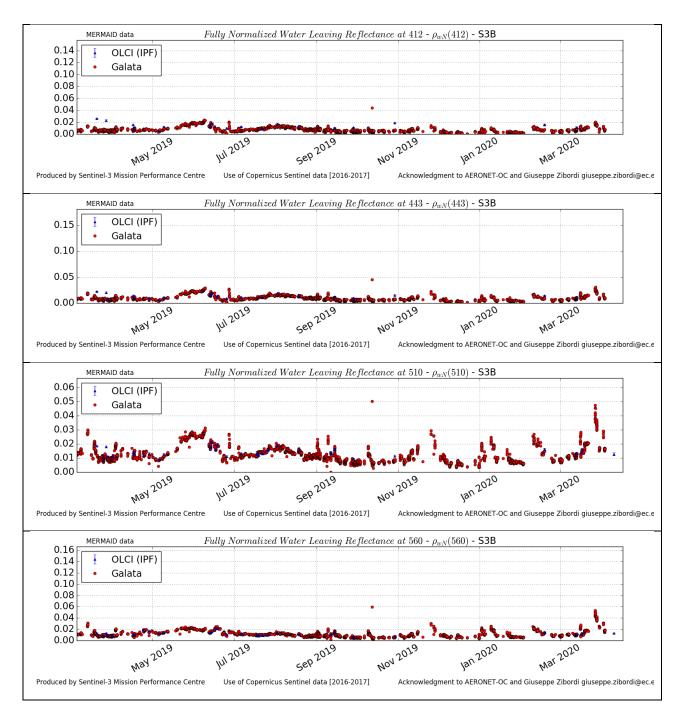


Figure 113: GALATA time series over current report period



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5.3 [OLCI-L2WLR-CV-430] – Algorithm performance over spatial and temporal domains

There has been no new result during the cycle. Last figures (cycle 27) are considered valid.

5.4 [OLCI-L2WLR-CV-510 & 520] – Cloud Masking & Surface Classification for Water Products

There has been no new result during the cycle. Last figures (cycle 27) are considered valid.

5.5 [OLCI-L2WLR-CV530] Validation of Aerosol Product

To validate OLCI's Aerosol product (aerosol optical thickness and Angstroem coefficient at 865nm), we continuously compare it with data from AERONET (Holben et al 1998), AERONET-OC (Zibordi et al 2009) and maritime AERONET (MAN: Smirnow et al 2009). This is an ongoing process, where co-located data are collected and analysed. Since, the AERONET L2 data is stringently quality controlled, it is published with a delay of up to 1 yr. The level 1.5 data, however, is similar to L2 with respect to direct transmission retrievals, including the optical thickness. Hence, we are using level 1.5 data. The OLCI-A data is either reprocessed or from after Nov 2017. We show the comparison of non-time-critical full-resolution data (wfr NT). Up to now 860 matchups (OLCI-A) and 360 matchups (OLCI-B) have been identified. For a matchup, the temporal distance between the satellite overpass and the AERONET acquisition was less than 30 minutes. Only OLCI measurements are used for the validation which are cloud-free (according to the standard cloud flags: cloud, cloud margin and cloud ambiguous) in an area of about 10x10 km² around the AERONET acquisition. Further, all recommended flags from Sentinel-3 OLCI Marine User Handbook (EUM/OPS-SEN3/MAN/17/907205) have been applied. Eventually, to reduce the influence of undetected (sub pixel or sub visual) clouds, only matchups have been used, where the standard deviation of the aerosol optical thickness within the 10x10 km² area was less than 0.3. The valid matchups evolved for AERONET and AERONET-OC are shown in Figure 114. The linear correlation of the aerosol optical thickness at 865nm is about 0.7, with a systematic bias of around 0.04 and a systematic overestimation of around 35-40%. The bias corrected root mean squared distance is 0.03. The Angstrom coefficients from maritime AERONET and OLCI are not directly comparable, since they belong to different wavelength ranges (AERONET: 870nm-440nm, OLCI: 865nm - 779nm). Nevertheless, there should be a co-relation. It is remarkable, that the majority of Angstroem coefficients found by OLCI and AERONET is around 1.5, pointing to non-maritime aerosols. The temporal evolution does not show significant changes.



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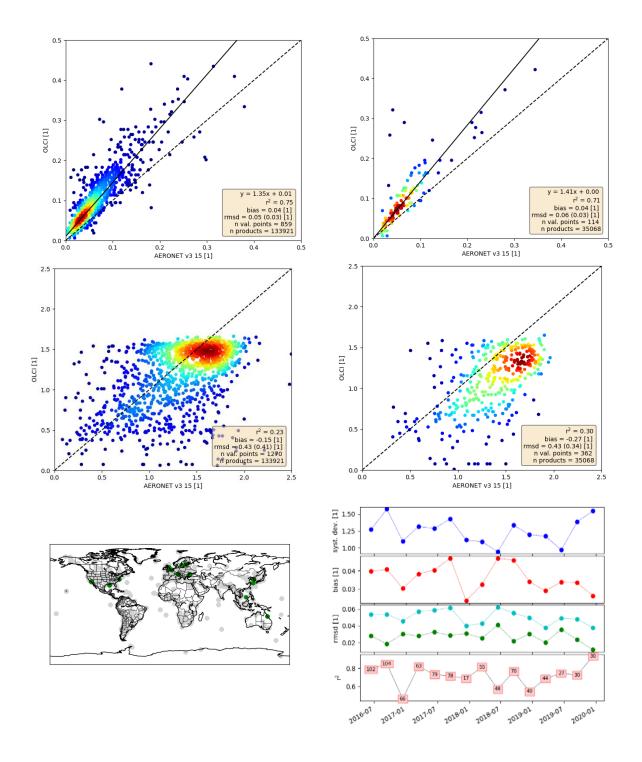


Figure 114: Upper and middle: Scatter plot of the aerosol products (upper: aerosol optical thickness, middle: Angstroem coefficient), derived from OLCI (A left, B right) and AERONET-OC measurements. Lower left: Positions of the AERONET-OC stations. Lower-right: Temporal evolution of different quality measures for the optical thickness derived from OLCI A (from top to bottom: systematic deviation factor, bias, root mean squared difference (with and without bias correction), explained variance (number in boxes are the numbers of matchups)).



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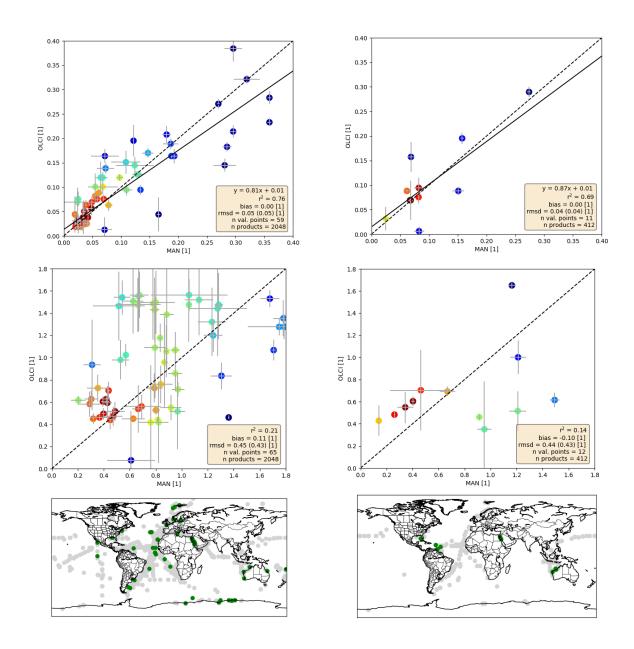


Figure 115: Upper and middle: Scatter plot of the aerosol products (upper: aerosol optical thickness, middle: Angstroem coefficient), derived from OLCI (A left, B right) and MAN measurements. Lower: Positions of the MAN acquisitions (left: OLCI A, right: OLCI B).

The 2000 (OLCI-A) and 400 (OLCI-B) MAN co-locations, acquired during ship cruises, evolved to 65 (OLCI-A) and 12 (OLCI-B) valid matchups, shown in Figure 115. Here the agreement of the aerosol optical thickness at 865nm is better than for the AERONET-OC comparisons. The linear correlation is still 0.7 and also the root mean squared distance is around 0.05, but no significant bias is found. The Angstrom coefficients don't show a significant co-relation, the clustering at 1.5 found for the AERONET-OC matchups, is not perceivable.



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5.6 [OLCI-L2WLR-CV-380] Development of calibration, product and science algorithms

There has been no new development on calibration, product and science algorithms during the cycle.



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6 Validation of Integrated Water Vapour over Land & Water

6.1 Preface

The OLCI L2 IWV processor distinguishes between ocean and land surfaces and works very differently above the respective surfaces. Hence, the validation of the IWV product is performed for both surface types independently.

The validation above land is performed via comparisons with ground based GNSS (Ware et al 2000) measurements, water vapor from AERONET (Pérez-Ramírez et al 2014, Holben et al 1998) and water vapor from ground based microwave radiometer at the *Atmospheric Radiation Measurement* (ARM) *Climate Research Facility* of the US Department of Energy ARM. (Turner et al. 2003, Turner et al. 2007).

Above ocean a quantitative verification has been undertaken using AERONET-OC (Zibordi et al 2009).

6.2 Quantitative validation using GNSS - Land

384,000 (OLCI-A) and 73000 (OLCI-B) potential matchups within the period of June 2016 (OLCI-A) January 2019 (OLCI-B) to March 2020 have been analysed yet. The scenes cover high and low elevations, however, the majority of the used SUOMI-NET ground stations are in North and Central America. The global service of SUOMI-NET has been ceased end 2018, thus OLCI-B colocations are restricted to in North America. Only OLCI measurements are taken for the validation which are above land and are cloud-free in an area of about 10x10 km² around the GNSS stations. For the cloud detection, the standard L2 cloud-mask has been applied (including the cloud ambiguous and cloud margin flags). The comparison of OLCI and GNSS shows a very high agreement (Figure 116). The correlation between both quantities is 0.98. The root-mean-squared-difference is 2.1-2.2 kg/m². The systematic overestimation by OLCI is 11%-12%. The bias corrected *rmsd* is 1.3-1.4 kg/m². Actually, both instruments behave equal. Figure 117 shows the temporal evolution of OLCI-A's quality measures. Interesting is the strong seasonal pattern of the bias. This clearly belongs to the seasonality of water vapor in North America. It is also partly visible in the systematic overestimation swinging between 7 and 12 %. This however could be a sampling effect too.

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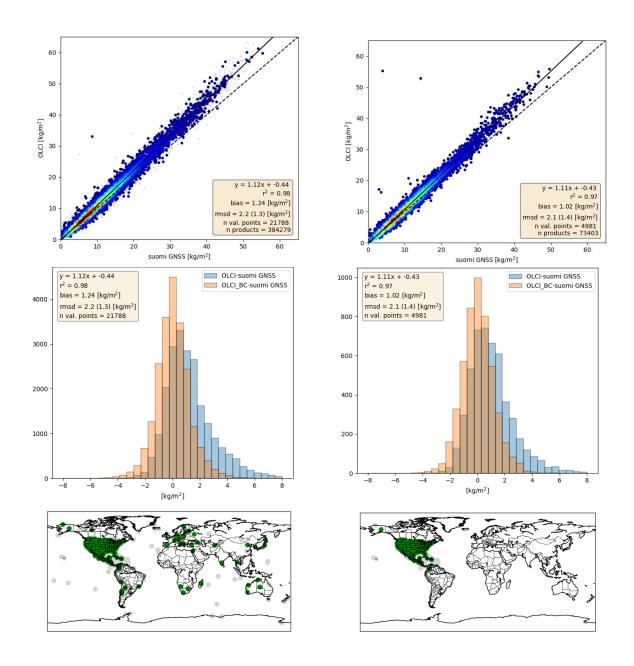


Figure 116: Upper: Scatter plot of the IWV products, derived from OLCI (A left, B right) above land and from SUOMI NET GNSS measurements. Middle: Histogram of the difference between OLCI (A: left, B: right) and GNSS (blue: original OLCI, orange: bias corrected OLCI). Lower: Positions of the GNSS (A: left, B: right).

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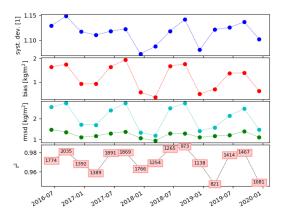


Figure 117: Temporal evolution of different quality measures for OLCI A (from top to bottom: systematic deviation factor, bias, root mean squared difference (with and without bias correction), explained variance (number in boxes are the numbers of matchups))

6.3 Quantitative validation using GNSS - Water

OLCIs IWV above water surfaces has been quantitatively validated via global GNSS measurements too, however with few additional assumptions:

- Since the GNSS stations are usually not directly above water, the closest water pixel (within 1km) is used for the satellite measurement.
- No height correction has been applied to account for the potentially elevated GNSS station.

For OLCI-A 64 matchups remain after filtering (Figure 118). They show a large bias of 10 kg/m² and a large scatter (>6 kg/m²). For OLCI-B the number of valid matchups is smaller, but all indications point to similar systematic deviations and retrieval noise. This is in accordance with the visual inspection.



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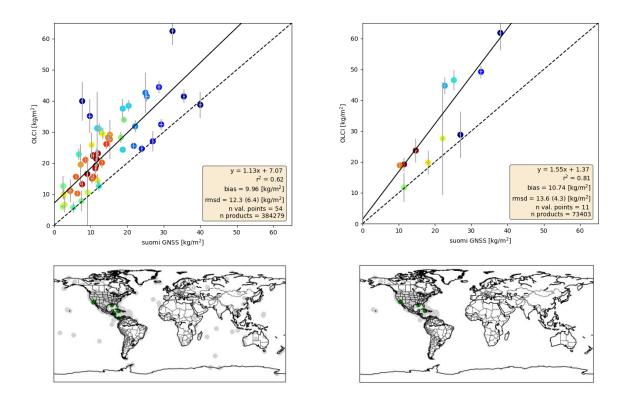


Figure 118: Upper: Scatter plot of the IWV products, derived from OLCI (A left, B right) above ocean and from SUOMI NET GNSS measurements. Lower: Positions of the GNSS (A: left, B: right).

6.4 Quantitative validation using AERONET IWV Retrievals – Land

Aeronet observations, allow the estimation of the total column of water vapour by measuring the extinction of the direct solar irradiance at 900 nm. The used operational algorithm is quite simple and eventually relies on a logarithmic fit (incl. quadratic corrections). AERONET data are better globally distributed than SUOMI-NET. Since, the AERONET L2 is stringently quality controlled, it is published with a delay of up to 1 yr. However, the L 1.5 data is similar to L2 with respect to direct transmission retrievals, including the water vapor. Only OLCI measurements are used for the validation which are cloud-free (according to the standard cloud flags: cloud, cloud margin and cloud ambiguous) in an area of about 10x10 km2 around the AERONET acquisition. From the 134000 (OLCI-A) and 35000 (OLCI-B) potential matchups until March 2020, 25000 (OLCI-A) and 6500 (OLCI-B) valid matchups could be used. (Figure 4). The correlation between both quantities is 0.96. The root-mean-squared-difference is 3.7 kg/m². The systematic overestimation by OLCI is 19%. The bias corrected rmsd is ~ 1.8 kg/m². The systematic deviation between OLCI and AERONET of 19% is significantly larger than the one found for GNSS and ARM (next section). We think that this stems from a dry bias of AERONET and accordingly deficits in the AERONET algorithm, but we have not investigated it deeper.

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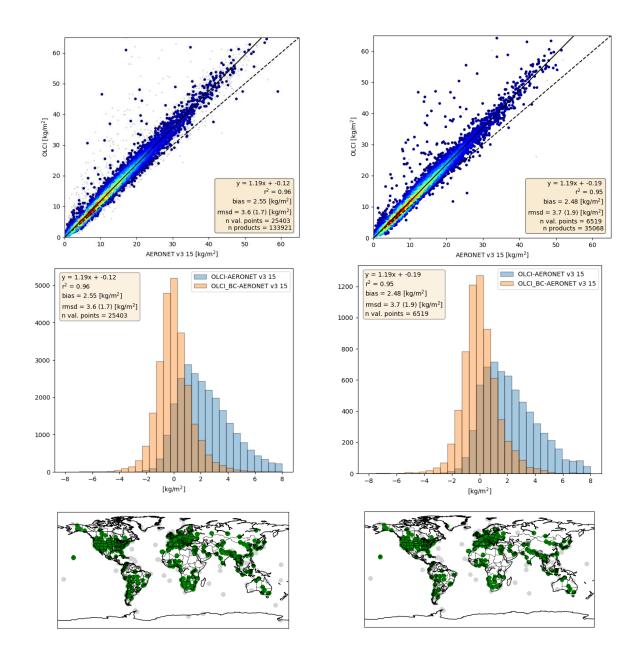


Figure 119: Upper: Scatter plot of the IWV products, derived from OLCI (A left, B right) above land and from Aeronet v.3 L1.5 measurements. Middle: Histogram of the difference between OLCI (A: left, B: right) and Aeronet (blue: original OLCI, orange: bias corrected OLCI). Lower: Positions of the Aeronet (A matchups: left, B matchups: right).

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6.5 Validation by AERONET IWV Retrievals – Ocean

OLCIs IWV above water surfaces has been quantitatively validated via global AERONET-OC measurements. All filters are as for land matchups. The remaining 1600 (OLCI-A) and 400 (OLCI-B) matchups show a large bias of about 9 kg/m², a large scatter (>6 kg/m²) and a systematic overestimation of about 20% (Figure 120). This is in accordance with the visual inspection and with the GNNS matchups (Figure 118) over oceans.

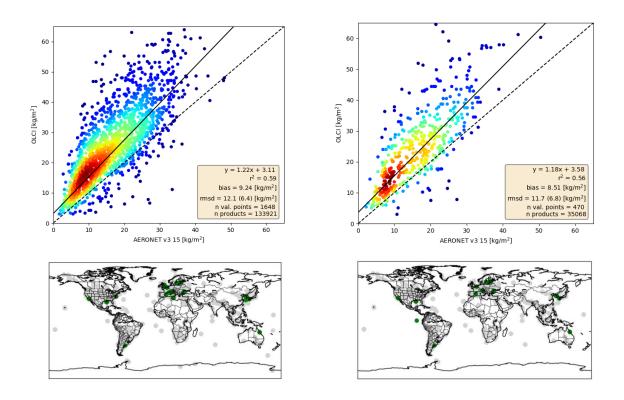


Figure 120: Upper: Scatter plot of the IWV products, derived from OLCI (A left, B right) above ocean and from Aeronet-OC v.3 L1.5 measurements. Lower: Positions of the used Aeronet match ups (A: left, B: right).

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6.6 Quantitative validation using ARM MWR IWV Retrievals – Land

Microwave radiometer measurements at the *Atmospheric Radiation Measurement* (ARM) *Climate Research Facility* of the US Department of Energy provides the ground truth with the highest accuracy (0.6 kg/m²). Only the SGP (southern great planes) site provided cloud free measurements. 2600 potential matchups within the period of June 2016 to November 2019 have been analysed yet. Only (OLCI-A) and 550 (OLCI-B) measurements are taken for the validation which are above land and are cloud-free in an area of about 10x10 km² around SGP. For the cloud detection, the standard L2 cloud-mask has been applied (including the cloud ambiguous and cloud margin flags), resulting in 135 (OLCI-A) and 34 (OLCI-B) valid matchups. The comparison shows a very high agreement. The correlation between both quantities is 0.99. The root-mean-squared-difference is 1.4 kg/m². The systematic overestimation by OLCI is 8%. The bias corrected *rmsd* is 0.8 kg/m², close to the uncertainty of ARM.

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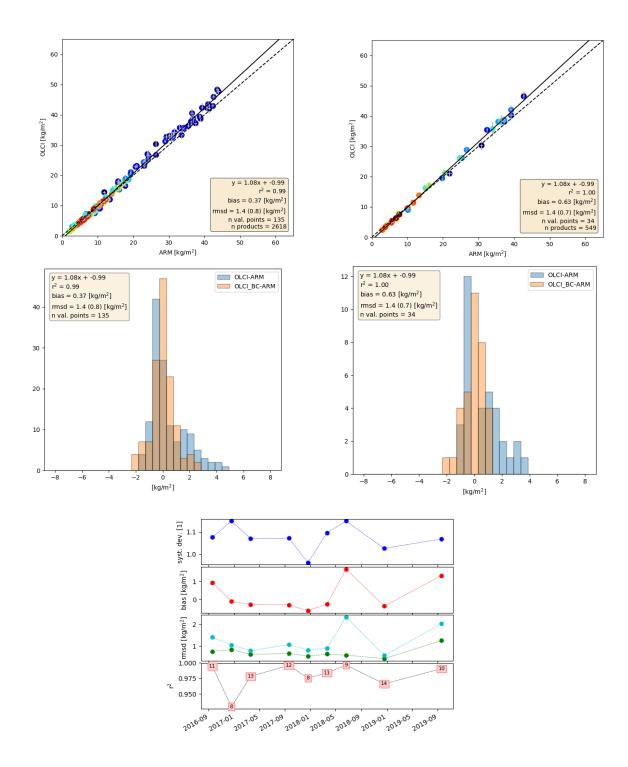


Figure 121: Upper: Scatter plot of the IWV products, derived from OLCI (A left, B right) above land and from ARM microwave measurements. Middle: Histogram of the difference between OLCI (A: left, B: right) and ARM-MWR (blue: original OLCI, orange: bias corrected OLCI). Lower: Temporal evolution of different quality measures for OLCI A (from top to bottom: systematic deviation factor, bias, root mean squared difference (with and without bias correction), explained variance (number in boxes are the numbers of matchups)).



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6.7 Summary

The validation exercise of the OLCI IWV product has been successful. It demonstrates that the product is stable and provides of high quality for retrievals above land surfaces.

- There is a systematic overestimation of around 8%-10% depending on the used ground base reference. The AMR microwave radiometer is regarded as the most accurate method, thus we assume that the bias is in the order of 9%. Further, we know that SUOMI-GNSS has a dry-bias of 3% with respect to ARM measurements (see Figure 122), which is fully consistent to our observations.
- Retrievals above ocean show an overestimation in transition zones between glint and off glint. This is a clear deficit of the description of the scattering-absorption interaction. Further the IWV has a large wet bias over ocean. A redesigned algorithm is necessary to overcome this. The new algorithm is under development.
- The IWV OLCI algorithm uses measurements at 865, 885 and 900 nm, while the bands at 935 and 1040 nm are not used. We expect better results, in particular less noise, if all relevant bands are used.

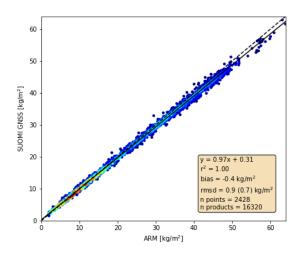


Figure 122 : ARM vs. GNSS IWV retrievals for the SGP site for the one-year period between Nov 2017 and Oct 2018. Only cloud free data has been used, according to the liquid/ice water path from the microwave radiometer



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7 Level 2 SYN products validation

There has been no new result during the cycle. Last figures (cycle 43/24) are considered valid.



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8 Events

For OLCI-A, four Radiometric Calibration Sequences have been acquired during Cycle 056:

- \$ S01 sequence (diffuser 1) on 11/03/2020 18:56 to 18:58 (absolute orbit 21175)
- S01 sequence (diffuser 1) on 22/03/2020 02:19 to 02:21 (absolute orbit 21322)
- So1 sequence (diffuser 1) on 31/03/2020 05:07 to 05:09 (absolute orbit 21452)
- \$05 sequence (diffuser 2) on 31/03/2020 06:48 to 06:50 (absolute orbit 21453)

For OLCI-B, five Radiometric Calibration Sequences have been acquired during Cycle 037:

- So1 sequence (diffuser 1) on 21/03/2020 17:15 to 17:17 (absolute orbit 9923)
- S01 sequence (diffuser 1) on 31/03/2020 01:05 to 01:07 (absolute orbit 10056)
- \$ S05 sequence (diffuser 2) on 31/03/2020 02:46 to 02:48 (absolute orbit 10057)
- S01 sequence (diffuser 1) on 08/04/2020 06:00 to 06:02 (absolute orbit 10173)
- S01 sequence (diffuser 1) on 12/04/2020 16:01 to 16:03 (absolute orbit 10236)

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9 Appendix A

Other reports related to the Optical mission are:

❖ S3 SLSTR Cyclic Performance Report, S3A Cycle No. 056, S3B Cycle No. 037 (ref. S3MPC.RAL.PR.02-056-037)

All Cyclic Performance Reports are available on MPC pages in Sentinel Online website, at: https://sentinel.esa.int

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