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

S3-A OLCI Cyclic Performance Report

Cycle No. 029

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Disclaimer

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1 Processing Baseline Version

IPF	IPF / Processing Baseline version	Date of deployment
OL1	06.07 / 2.29	CGS: 05/07/2017 13:00 UTC PAC: 05/07/2017 12:50 UTC
OL2	06.11/2.23	CGS: 11/10/2017 08:53 UTC (NRT)
		PAC: 11/10/2017 08:15 UTC (NTC)
SY2	06.12 / 2.26	PAC: 11/01/2018 10:52 UTC
SY2_VGS	06.12 / 2.26	PAC: 11/01/2018 10:52 UTC



2 Instrument monitoring

2.1 CCD temperatures

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 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.





Figure 2: Same as Figure 1 for diffuser frames.

2.2 Radiometric Calibration

Four OLCI Radiometric Calibration Sequences have been acquired during Cycle 029:

- S01 sequence (diffuser 1) on 12/03/2018 10:57 to 10:59 (absolute orbit 10761)
- S01 sequence (diffuser 1) on 22/03/2018 13:18 to 13:20 (absolute orbit 10905)
- S04 sequence (diffuser 1) on 31/03/2018 21:08 to 21:10 (absolute orbit 11038)
- S05 sequence (diffuser 2) on 31/03/2018 22:49 to 22:51 (absolute orbit 11039)

The acquired Sun azimuth angles are presented on Figure 3, on top of the nominal values without Yaw Manoeuvre (i.e. with nominal Yaw Steering control of the satellite).





Figure 3: Sun azimuth angles during acquired Radiometric Calibrations (diffuser frame) on top of nominal yearly cycle (black curve). Diffuser 1 with diamonds, diffuser 2 with crosses, 2016 acquisitions in blue, 2017 in green, 2018 in red.



Figure 4: Sun geometry during radiometric Calibrations on top of characterization ones (diffuser frame)

This section presents the overall monitoring of the parameters derived from radiometric calibration data and highlights, if present, specificity of current cycle data.



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 5.



Figure 5: 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.

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 6: 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.



Figure 7: 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. Periodic noise amplitude is high in camera 2, 3 and 4. It is lower in camera 4 and small in camera 1.



Figure 8: same as Figure 7 for smear band.

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Figure 7 and Figure 8 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 and consequently to highlight the shape of the PN. Maps are focused on the last 200 EAST detectors where PN occurs.

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 hot pixel impacting one of the "East blind pixels" for camera 4 smear band, presented in cycle #26 report, is still present.

In order to take into account the presence of the above mentioned 'hot pixel', as well as the modification of PN phase due to the last instrument anomaly (orbit 9572), a CAL_AX containing an update of the Dark LUTs (derived from the 25/01/2017 calibration) was delivered to MPC-CC on 08/02/2018 and deployed in PDGS on 14/03/2018.PDGS.

Dark Currents

Dark Currents (Figure 9) 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 10).





Figure 9: 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 10: left column: ACT mean on 400 first detectors of 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. A possible explanation 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.

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

2.2.2.1 Instrument response monitoring

Figure 11 shows the gain coefficients of every pixel for two OLCI channels, Oa1 (400 nm) and Oa21 (1020 nm), highlighting the significant evolution of the instrument response since early mission.





Figure 11: 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 11, however are derived using the ground BRDF model – as the only one available in the operational processing software so far – 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 12 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.





Figure 12: 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.

2.2.2.2 Instrument evolution modelling

As mentioned in cycle #22 report, the OLCI Radiometric Model has been refreshed, and put in operations the 11/10/2017. The model has been derived on the basis of an extended Radiometric Calibration dataset (from 25/04/2016 to 27/08/2017), and 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 seven months) remains better than 0.1% – except for channels Oa1 (400nm) and Oa21 (1020 nm), at about 0.18% and 0.14% respectively – when averaged over the whole field of view (Figure 13) even if a small drift of the model with respect to most recent data is now visible. The previous model, trained on a Radiometric Dataset



limited to 12/03/2017, shows a stronger drift of the model with respect to most recent data (Figure 14). Comparison of the two figures shows the improvement brought by the updated Model.



Figure 13: RMS performance of the Gain Model of current Processing Baseline as a function of orbit.



Figure 14: RMS performance of the Gain Model of previous Processing Baseline as a function of orbit.

The overall instrument evolution since channel programming change (25/04/2016) is shown on Figure 15.





Figure 15: Camera-averaged instrument evolution since channel programming change (25/04/2016) and up to most recent calibration (31/03/2018) versus wavelength.

The overall per camera performance, as a function of wavelength, and at each orbit is shown on Figure 16 as the average and standard deviation of the model over data ratio.

Finally, Figure 17 to Figure 19 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 17 to Figure 19 with their counterparts in Report of Cycle 22 clearly demonstrate the improvement brought by the new model whatever the level of detail.



Figure 16: For the 5 cameras: 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).



Figure 17: 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.





Figure 18: same as Figure 14 for channels Oa7 to Oa14.





Figure 19: same as Figure 17 for channels Oa15 to Oa21.



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

There has been one calibration sequence S05 (reference diffuser) acquisition during cycle 029:

S05 sequence (diffuser 2) on 31/03/2018 22:49 to 22:51 (absolute orbit 11039)

Immediately following (next orbit) the associated S04 (nominal diffuser) sequence in order to compute ageing:

S04 sequence (diffuser 1) on 31/03/2018 21:08 to 21:10 (absolute orbit 11038)

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 20 for band Oa01 and in Figure 21 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.



Figure 20: diffuser 1 ageing for spectral band Oa01. We see strong ACT low frequency structures that are due to residual of BRDF modelling.



Figure 21: same as Figure 20 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 22.

Figure 20 and Figure 21 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 22 where we can see that this band is impacted by ageing of the diffuser.



Figure 22: same as Figure 20 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 23 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.





Figure 23: Diffuser 1 ageing as a function of wavelength (or spectral band). Ageing is clearly visible in spectral band #1 to #5.

Figure 24 shows the evolution of the 5 camera averaged ageing as a function of time.



Figure 24: Camera averaged ageing (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

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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 25).



Figure 25: 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), at the time of cycle #24 (green curve) and at the time of cycle #20 (black curve)

In Figure 25, we see that the Ageing slopes have not significantly changed between the current Cycle and the last three cycles with a S05 sequence (cycles #27, #24 and #20, the latter having been used to derived the Ageing Correction model used for the currently operational Gain Model).

The exposure time dependent ageing model has been used to derive a new Gain Model, put in operations on 11th October 2017. A dedicated Verification Report has been issued (S3MPC.ACR.VR.025).

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

There has been no Calibration ADF generation during the current cycle.

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]

This activity has not evolved during cycle 029 and results presented in previous report are still valid.



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

There have been two Spectral Calibration acquisitions during the reporting period:

- One S02/S03:
 - S02 sequence (diffuser 1) on 19/03/2018 11:15 to 11:16 (absolute orbit 10861)
 - S03 sequence (Erbium doped diffuser) on 19/03/2018 12:56 to 12:57 (absolute orbit 10862)
- And one S09 (Fraunhofer lines):
 - S09 sequence on 19/03/2018 09:04:36 to 09:04:42 (absolute orbit 10860), for the first time with a duration reduced to 4.4 seconds (100 FR frames).

It was the first S09 acquisition with hundred frames only, shown Figure 26, contrary to the previous acquisitions with several thousand lines each. As expected and tested with subsets of the previous calibrations, the short calibration sequence worked flawless and can be kept in future.







Figure 26: Ground track and grey scale image for two latest S09 acquisitions. Left: March 2018, the small blue dot is the ground track of the acquisition. Right: November 2017 Eastern Europe → north Sahara.

The S02/S03 and S09 data have been processed and analysed to assess OLCI spectral long-term evolution. The long term evolution of spectral calibration obtained with calibration sequence S02/S03 is presented in Figure 27 and Figure 28 and the one obtained with calibration sequence S02 solar and S09 is presented in Figure 29.



Figure 27: across track spectral calibration from all S02/S03 sequences since the beginning of the mission. Top plot is spectral line 1, middle plot is spectral line 2 and bottom plot spectral line 3.



Figure 28: camera averaged spectral calibration as a function of orbit number (all spectral S02/S03 calibrations since the beginning of the mission are included). Top plot is spectral line 1, middle plot is spectral line 2 and bottom plot spectral line 3.





Figure 29: spectral calibration relative to the one at orbit 380 (march 2016), as a function of time derived from all S09 sequences and all S02 sequences except the very last one (march 2018) and the one near orbit 8000. The last calibration (S09) is from March 2018. From left to right column: the 5 cameras. From top to bottom: Used absorption line: 405 nm (S02), 485 nm (S09), 520 nm (S02), 656 nm (S09), 770 nm (S09), 800 nm (S02) and 854 nm (S09).

We see that the long term evolution of the spectral calibration obtained with sequence S09 and S02 solar (Figure 29) is in rather good agreement with the one obtained with sequence S02/S03 (Figure 28). Indeed, for camera 1, 2, 3 and 4, we observe for both methods a positive trend of the spectral calibration at the beginning of the mission which is now rather stabilized, and for camera 5, an obvious negative trend since almost the beginning of the mission. The temporal evolution of the spectral calibration drift is smaller than 0.2 nm and the change with respect to the values included in the Auxiliary Data files is less than 0.1 nm. However camera 5, and to a lesser extend camera 2, do further evolve thus and an evolution of the Auxiliary Parameters impacted by the instrument spectral model, reflecting the current state of the instrument, may have to be considered in the future, even if all cameras but camera 5 show a decreasing change rate. The very good point, on the other hand is that the average spectral shift between the various cameras is slowly decreasing (see Figure 28). Further,



since the observation period covers two years more or less, it can be concluded that the spectral shifts do not follow annual variations.



Figure 30: Temporal evolution of OLCI's single band full width half maximum estimated using S02 solar and S09 calibration modes. The first column belongs to camera 1 (east on descending node), the 5th column to camera 5 (west on descending node). The first calibration is from March 2016, the last from March 2018

The single element bandwidth (expressed in terms of full width at half maximum) does not show any significant temporal evolution, as shown in Figure 30. Indeed, camera 5 shows a very small trend towards a larger bandwidth, however much smaller than the variations within and between the cameras.



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

2.4.1 SNR from Radiometric calibration data

SNR computed for all calibration data (S01, S04 and S05 sequences) as a function of band number is presented in Figure 31.

SNR computed for all calibration data as a function of orbit number for band Oa01 (the less stable band) is presented in Figure 32.

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



Figure 31: 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.





Figure 32: 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: $SNR(L) = SNR(L_{ref}) \cdot \int_{L_{ref}}^{L} dL_{ref}$

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: 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	C	1	C	2	C	3	C	4	C	5	A	.11
nm	LU	RQT	avg	std	avg	std	avg	std	avg	std	avg	std	avg	std
400	63	2188	2420	6.2	2397	6.8	2326	6.4	2373	11.6	2281	9.8	2359	7
412	74.1	2061	2395	7.3	2408	5.5	2340	4.8	2402	4.5	2386	6.8	2386	3.8
442	65.6	1811	2161	5.2	2199	5.5	2166	4.7	2185	4.2	2197	4.6	2182	3.3
490	51.2	1541	2000	5.1	2036	5.4	1996	3.9	1981	4	1988	5.1	2000	3.6
510	44.4	1488	1980	5.3	2013	5.1	1984	5	1966	4.8	1985	4.8	1985	4
560	31.5	1280	1776	4.4	1802	4.4	1802	4.8	1794	4.1	1818	3.7	1798	3.2
620	21.1	997	1591	4.2	1610	4.2	1625	3.1	1593	3.3	1615	3.8	1607	2.7
665	16.4	883	1547	4.6	1559	4.2	1567	3.9	1533	4	1560	4	1553	3.3
674	15.7	707	1329	3.3	1338	3.7	1350	2.9	1324	2.9	1342	4	1336	2.5
681	15.1	745	1320	3.7	1327	3.1	1337	2.9	1314	2.6	1333	3.9	1326	2.3
709	12.7	785	1421	4.6	1421	4.4	1435	3.6	1414	3.6	1430	3.3	1424	3.1
754	10.3	605	1127	3.3	1120	3	1134	3.8	1124	2.6	1138	3.2	1129	2.7
761	6.1	232	502	1.3	498	1.2	505	1.3	500	1.1	507	1.5	502	1
764	7.1	305	663	1.7	657	1.5	667	2.2	661	1.7	669	2.2	663	1.5
768	7.6	330	558	1.7	554	1.4	562	1.4	556	1.6	564	1.4	559	1.2
779	9.2	812	1515	5.2	1497	5.1	1523	5.5	1510	5.4	1525	5.1	1514	4.6
865	6.2	666	1244	3.8	1213	4.2	1238	4.2	1246	3.8	1250	3.1	1238	3.3
885	6	395	823	1.8	801	1.7	814	2.1	824	1.5	831	1.9	819	1.3
900	4.7	308	691	1.6	673	1.3	683	1.7	693	1.5	698	1.5	687	1.1
940	2.4	203	534	1.1	522	1.1	525	1	539	1.1	542	1.3	532	0.8
1020	3.9	152	345	0.8	337	0.7	348	0.7	345	0.8	351	0.7	345	0.5

2.4.2 SNR from EO data

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



2.5 Geometric Calibration/Validation

OLCI georeferencing performance was slowly degrading among the last months, down to the point at which compliance to the requirement (0.5 pixel RMS) was not met anymore. A new geometric calibration has been done by ESTEC, provided to S3-MPC for formatting into the appropriate ADF and validation (successful and reported in S3MPC.ACR.VR.030); it was put in production on the 14th of March 2018.

The following figures show time series of the overall RMS performance (requirement criterion) and of the across-track and along-track biases for each camera. The performance improvement on the 14/03/2018 is obvious on each figure and compliance is comfortably met again (Figure 33). Unfortunately, an update of the MPMF took place shortly after the Calibration ADF update and drastically reduced the production rate of the GeoCal validation data (Figure 34), explaining a higher variability in the performance estimates 19/03/2018 and 29/03/2018; nevertheless RMS values remain around 0.3 pixel from 14/03 on. The most dramatic improvements affect along-track bias of Camera 3 (Figure 37) and across-track biases of Cameras 4 and 5 (Figure 38 & Figure 39, respectively).



Figure 33: overall OLCI georeferencing RMS performance time series over the whole monitoring period (left) and restricted to March 2018 (right)



Figure 34: number of validated control points corresponding to the performance time series of Figure 33 for the same periods (complete, left, and restricted to March 2018, right).



Figure 35: across-track (left) and along-track (right) georeferencing biases time series for Camera 1.



Figure 36: same as Figure 35 for Camera 2.



Figure 37: same as Figure 35 for Camera 3.



Figure 39: same as Figure 35 for Camera 5.

Examples of residual distributions are provided below (Figure 40), 2 days before and 2 days after the ADF update, for Camera 3 (the most affected by the performance degradation), to illustrate the impact of the re-calibration.





Figure 40: histograms of geolocation errors for the along-track (left) and across-track (right) directions, examples of 12/03/2018 (top, 2 days before the ADF update) and 16/03/2018 (bottom, 2 days after), Camera 3.



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 <u>http://s3etrac.acri.fr/index.php?action=generalstatistics</u>

- 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). Note that due to a technical issue, S3ETRAC production rate has been reduced in December and came back to nominal only recently. As a consequence, figures below do not represent the full production of December 2017.



Figure 41: summary of S3ETRAC products generation for OLCI (number of OLCI 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).

3.1.2 Radiometric validation with DIMITRI

Highlights

- Run Rayleigh and Desert methods over the available products until 9th April 2018.
- About 70 new cloud free products from Cycle-29 are used in this analysis. The results (Rayleigh, Glint and PICS) are consistent with the previous cycle over the used CalVal sites.
- Good stability of the sensor could be observed, nevertheless, the time-series average shows higher reflectance over the VNIR spectral range with biases of 2%-4% except bands Oa06-Oa09
- Bands with high gaseous absorption are excluded.
- SLSTR RBT-NT products are successfully ingested over PICS, the results analysis is on-going.



I-Validation over PICS

- Downloading and ingestion of all the available L1B-LN1-NT products in the S3A-Opt database over the 6 desert CalVal-sites (Algeria3 & 5, Libya 1 & 4 and Mauritania 1 & 2) has been performed until 9th of April 2018.
- 2. The results are consistent overall the six used PICS sites (Figure 42). OLCI reflectance shows a good stability over the analysed period.
- 3. The temporal average over the period April 2016 April 2018 of the elementary ratios (observed reflectance to the simulated one) shows values higher than 2% (mission requirements) over all the VNIR bands (Figure 43). The spectral bands with significant absorption from water vapour and O₂ (Oa11, Oa13 Oa14 and Oa15) are excluded.
- 4. Algeria-3 site shows lower reflectance for channel Oa17 (865 nm) than the other PICS since May 2017. This event is observed on Sentinel-2/MSI and Sentinel-3/SLSTR images too. It is most likely related to human/industrial activity in the area. The impact of these activities seems to have decreased and Algeria-3 results are more consistent with the other PICS.





Figure 42: Time-series of the elementary ratios (observed/simulated) signal from S3A/OLCI for (top to bottom) bands Oa03, Oa8 and Oa17 respectively over Six PICS Cal/Val sites. Dashed-green and orange lines indicate the 2% and 5% respectively. Error bars indicate the desert methodology uncertainty.





Figure 43: The estimated gain values for S3A/OLCI over the 6 PICS sites identified by CEOS over the period April 2016 – April 2018 as a function of wavelength. Dashed-green and orange lines indicate the 2% and 5% respectively. Error bars indicate the desert methodology uncertainty.

II- Cross-mission Intercomparison over PICS

X-mission Intercomparison with MODIS-A and MSI-A has been performed until January and April 2018 respectively. Figure 44 shows time-series of the elementary ratios from S2A/MSI, Aqua/MODIS and S3A/OLCI over the LYBIA4 site over the period April-2016 until April 2018 (for OLCI).

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

Figure 45 shows the estimated gain over the different time-series from different sensors (MERIS (3REP archive), MSI-A, MODIS-A and OLCI) over PICS for the common bands. The spectral bands with significant absorption from water vapour and O_2 are excluded. OLCI-A seems to have higher gain (Figure 45) than the other sensors, which means that OLCI-A has higher reflectance that the ones simulated by the PICS method.





Figure 44: Time-series of the elementary ratios (observed/simulated) signal from (black) S2A/MSI, (blue) S3A/OLCI, and (Cyan) MODIS-A for band Oa17 (865nm) over the LIBYA4 site. Dashed-green and orange lines indicate the 2% and 5% respectively. Error bars indicate the desert methodology uncertainty.





Figure 45: Ratio of observed TOA reflectance to simulated one for (black) MERIS/3REP, (green) S2A/MSI, (cyan) Aqua/MODIS and (blue) S3A/OLCI averaged over the six PICS test sites as a function of wavelength.

III-Validation over Rayleigh

Rayleigh method has been performed over the available mini-files on the Opt-server until April 2018. The results produced with the configuration (ROI-AVERAGE) are consistent with the results of PICS method but slightly higher than the Cycles 27 ones due to the application of more strict criteria of Rayleigh method. While bands Oa01-Oa05 display a bias values between 2%-5%, bands Oa6-Oa9 exhibit biases at the edge of the 2% mission requirement (Figure 46 and Figure 47).



Figure 46: The estimated gain values for S3A/OLCI over the 6 Ocean CalVal sites (Atl-NW_Optimum, Atl-SW_Optimum, Pac-NE_Optimum, Pac-NW_Optimum, SPG_Optimum and SIO_Optimum) over the period November 2016 – March 2018 as a function of wavelength. Dashed-green, and orange lines indicate the 2%, 5% respectively. Error bars indicate (black) the methodology uncertainty and (grey) the standard deviation over the 6 CalVal sites.

550

Wave Length (nm)

600

650

700

500

IV-Validation over Glint

400

450

Glint calibration method with the configuration (ROI-PIXEL) has been extended over the period December 2016 – April 2018 from the available mini-files. The outcome of this analysis shows a good consistency with Rayleigh and the desert outputs over the NIR spectral range Oa06-Oa09, while bands Oa12, Oa16, Oa17 and Oa18 are within the 2% mission requirements (see Figure 47).



Figure 47: The estimated gain values for S3A/OLCI from Glint, Rayleigh and PICS over the period April 2016 – April 2018 for PICS and December 2016- March 2018 for Glint and Rayleigh methods as a function of wavelength. We use the gain value of Oa8 from Rayleigh method as reference gain for Glint. Dashed-green and orange lines indicate the 2% and 5% respectively. Error bars indicate the methods uncertainties.

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3.1.3 Radiometric validation with OSCAR

The average OSCAR Rayleigh results and the standard deviation calibration are shown below (Figure 48). Observed biases for Oa01-Oa05 are between 3% - 4.7%, for Bands Oa6-Oa9 observed biases are less (roughly within the 2 % mission requirement). Observed biases are slightly higher (between 0.001 to 0.006, i.e. 0.1 to 0.6%) than for the period July 2017 until November 2017 but this might be related to the smaller amount of scenes included in the current average.



Figure 48: OSCAR Rayleigh Calibration results: weighted average over all sites and standard deviation for Jan 2017 till March 2018.

The average OSCAR Glitter results are shown on Figure 49, excluding the bands in the Blue spectral region and the atmospheric absorption bands. The results in Figure 49 are "relative" interband calibration results. This means that results are given relative to the reference band, which is a Red band at 655 nm. OSCAR glitter results are almost identical to the results reported in previous period.



Figure 49: OSCAR Glitter results: weighted average over all sites and standard deviation for Jan2018 till March 2018.

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

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



4 Level 2 Land products validation

4.1 [OLCI-L2LRF-CV-300]

4.1.1 OLCI Global Vegetation Index (OGVI), a.k.a. FAPAR

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

4.1.2 OLCI Terrestrial Chlorophyll Index (OTCI)

There has been no new result during the cycle. Last figures (cycle 28) are considered valid.

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.



5 Level 2 Water products validation

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

There has been no update of the SVC (System Vicarious Calibration) during Cycle 029. Last figures (cycle 17) are considered valid.

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.

Activities done

- The focus for this time period has been on the rolling archive None Time Critical (NT) data from February 16th onward. Although the rolling archive is populated regularly there are very few data available for statistical analysis. No issue have been identified neither in the extraction process nor in OLCI data. The very high cloud coverage other Europe this last three month is most probably the reason of such pour number of matchups.
- All extractions and statistics have been regenerated from February 16th onward (rolling archive availability) for WFR data. The available matchups therefore cover the end of winter to spring situation.
- At best 6 matchups at 490 and 560nm are useful for this time period. No statistically reliable interpretation can therefore be driven for this time period. Despite the poor number of matchup, OLCI appear to perform nominally.

Overall Water-leaving Reflectance performance

Figure 50 and Figure 51 below presents the scatterplots with statistics of OLCI FR versus in situ reflectance computed for the NT dataset. Both current and previous time period are displayed as a comparison since very few data are available on the current time period. The data considered correspond to the latest processing baseline i.e. including SVC.. Table 2 to Table 10 below summarise the statistics over the previous reporting period. The current one is not present as less than 6 matchups would not provide reliable statistical results.





Figure 50: Scatter plots of OLCI versus in situ radiometry (FR data). Previous time period (left), current time period (right)



Figure 51: Scatter plots of OLCI versus in situ radiometry (FR data). Previous time period (left), current time period (right)

Table 2: FR statistics over December 2016-March 2017 reporting period, cyclic report#17; FR data.

lambda	Ν	RPD	RPD	MAD	RMSE	slope	int.	r2
412	25	70,55%	77,47%	0,0055	0,0071	0,9486	0,0061	0,6787
443	25	43,34%	44,27%	0,0045	0,0056	1,1251	0,0028	0,9037
490	24	28,53%	28,53%	0,0048	0,0059	1,1634	0,0016	0,9611
510	2	31,69%	31,69%	0,0091	0,0093	2,0459	-0,0207	1,0000
560	17	15,44%	16,95%	0,0037	0,0052	1,1350	0,0003	0,9655
665	25	10,56%	34,24%	0,0010	0,0032	1,3661	-0,0013	0,9236

Table 3: FR statistics over February 2017-April 2017 reporting period, cyclic report#18; FR data.

lambda	Ν	RPD	RPD	MAD	RMSE	slope	int.	r2
412	60	88.15%	93.77%	0.0052	0.0066	1.0404	0.0048	0.6176
443	60	46.70%	50.43%	0.0038	0.0049	1.1195	0.0026	0.8046
490	59	31.38%	32.56%	0.0039	0.0046	1.1397	0.0019	0.9263
510	19	27.06%	27.06%	0.0050	0.0055	1.1474	0.0021	0.9486
560	53	13.42%	16.58%	0.0024	0.0035	1.1281	0.0001	0.9379
665	51	1.02%	29.79%	0.0000	0.0012	1.0202	-0.0001	0.7892



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Table 4 FR statistics over April 2017-June 2017 reporting period, cyclic report#19; FR data.

lambda	N	RPD	RPD	MAD	RMSE	slope	intercept	r2
400	2	17.9%	17.9%	0.0088	0.0100	-2.3992	0.1784	1.0000
412	15	66.3%	66.3%	0.0055	0.0062	1.0618	0.0046	0.9611
443	15	36.7%	37.0%	0.0037	0.0044	1.1107	0.0023	0.9454
490	20	32.1%	32.3%	0.0038	0.0044	1.0153	0.0036	0.8224
510	10	35.9%	35.9%	0.0045	0.0048	0.8626	0.0064	0.7505
560	21	17.0%	21.9%	0.0020	0.0034	1.0925	0.0006	0.9205

 Table 5: FR statistics over May 1st to July 10th reporting period, cyclic report#20; FR data.

lambda	Ν	RPD	RPD	MAD	RMSE	slope	intercept	r2
412	35	30.5%	38.2%	0.0025	0.0060	0.9699	0.0033	0.9364
443	43	25.2%	32.9%	0.0023	0.0061	1.0444	0.0012	0.9546
490	52	15.2%	22.2%	0.0020	0.0055	1.0462	0.0007	0.9756
510	21	24.1%	24.9%	0.0026	0.0039	1.1577	0.0004	0.9946
560	52	2.4%	11.1%	0.0004	0.0045	1.0196	-0.0002	0.9701
665	32	-6.9%	17.7%	-0.0002	0.0023	0.9830	-0.0001	0.8423

Table 6: FR statistics over the current reporting period (July 11th to August 23rd), cyclic report#21; FR data.

lambda	Ν	RPD	RPD	MAD	RMSE	slope	intercept	r2
412	19	18.0%	32.2%	0.0008	0.0066	1.0075	0.0006	0.9346
443	24	10.2%	24.1%	0.0012	0.0072	1.0752	-0.0012	0.9524
490	32	8.0%	18.8%	0.0012	0.0062	1.0504	-0.0005	0.9743
510	10	17.6%	19.3%	0.0011	0.0014	0.9560	0.0014	0.6316
560	32	-1.0%	13.0%	-0.0002	0.0055	1.0179	-0.0008	0.9618
665	22	-10.8%	18.4%	-0.0004	0.0027	0.9028	0.0003	0.7552

Table 7: FR Statistics over the current reporting period (July 1s^h to September 7th), cyclic report#22; FR data.

lambda	Ν	RPD	RPD	MAD	RMSE	slope	intercept	r2
412	6	81.5%	95.7%	0.0017	0.0064	0.6848	0.0063	0.7589
443	7	31.6%	49.7%	0.0003	0.0041	0.8661	0.0026	0.9401
490	11	5.8%	20.1%	0.0003	0.0022	0.9909	0.0004	0.9818
510	3	13.0%	20.2%	0.0009	0.0015	1.1289	0.0000	0.1477
560	11	-4.5%	12.9%	-0.0009	0.0021	0.9270	0.0004	0.9784
665	7	-22.5%	22.5%	-0.0008	0.0009	1.0191	-0.0009	0.9618

Table 8: FR Statistics over the current reporting period (September 13th to November 4th), cyclic report#23; FR data.

lambda	N	RPD	RPD	MAD	RMSE	slope	intercept	r2
400	0	None	None	None	None	None	None	None
412	7	-2.1%	32.6%	0.0006	0.0049	2.7334	-0.0157	0.7427
443	10	-2.2%	22.0%	-0.0001	0.0030	1.4778	-0.0043	0.5329
490	16	0.4%	11.9%	0.0000	0.0019	0.9282	0.0008	0.5065
560	16	-5.9%	13.7%	-0.0004	0.0014	1.0994	-0.0013	0.8961
665	4	-24.8%	24.8%	-0.0003	0.0003	1.0428	-0.0004	0.9994

2	Sentinel-3 MPC	Ref.:	S3MPC.ACR.PR.01-029
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Table 9 Statistics over the current reporting period (September 1st to November 24th), cyclic report#24; FR data.

lambda	Ν	RPD	RPD	MAD	RMSE	slope	intercept	r2
400	14	-9.9%	11.7%	-0.0049	0.0065	0.9241	-0.0012	0.5049
412	18	-14.1%	16.1%	-0.0057	0.0072	0.8357	0.0005	0.9427
443	24	-12.4%	16.2%	-0.0033	0.0046	0.8364	0.0005	0.9605
490	31	-5.5%	10.3%	-0.0011	0.0021	0.8081	0.0021	0.8710
510	14	-8.1%	10.8%	-0.0009	0.0015	2.5638	-0.0183	0.2207
560	30	-5.1%	12.1%	-0.0003	0.0011	1.0427	-0.0006	0.9236

Table 10; Statistics over the current reporting period (September 1st to November 26th), (FR data).

lambda	N	RPD	RPD	MAD	RMSE	slope	intercept	r2
400	14	-9.9%	11.7%	-0.0049	0.0065	0.9241	-0.0012	0.5049
412	30	-4.3%	18.6%	-0.0030	0.0061	0.7920	0.0026	0.9417
443	38	-6.6%	15.4%	-0.0020	0.0039	0.8056	0.0017	0.9438
490	49	-4.0%	10.4%	-0.0008	0.0020	0.8235	0.0018	0.8666
510	14	-8.1%	10.8%	-0.0009	0.0015	2.5638	-0.0183	0.2207
560	47	-6.6%	16.2%	-0.0005	0.0015	0.9610	-0.0002	0.8234

Figure 52 and **Figure 53** below present AAOT and Galata in situ and OLCI time series over the current reprocessing period. As mentioned for scatterplot analysis, the in situ time series has produced sufficient data but very few matchups are available on the time period.







Figure 53: AERONET-OC Galata time series over current report period



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

There has been no new result during the cycle. Last figures (cycle 28) are considered valid.

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

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



6 Validation of Integrated Water Vapour over Land & Water

Our calibration database that connects the *ProductIDs* of OLCI L2 data available at the data hubs (Copernicus, Eumetsat CODA and Eumetsat CODA Rep) has been extended to an additional source of ground truth data: microwave radiometer measurements at the *Atmospheric Radiation Measurement* (ARM) *Climate Research Facility* of the US Department of Energy (Turner et al. 2003, Turner et al. 2007). This data is spatially limited but provides the ground truth with the highest accuracy (0.6 kg/m²). Currently 3 ARM sites are operated continuously, only the SGP (southern great planes) site provided cloud free measurements (Figure 54). For a matchup, the temporal distance between the satellite overpass and the ARM 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 acquisition.



Figure 54: Position of the ARM stations used for the IWV validation. Currently only at the SGP site (southern great planes, red dot) cloud free matchups have been found.

The comparison of OLCI and ARM shows an almost perfect agreement (Figure 55). The correlation between both quantities is 1. The root-mean-squared-difference is 1.3 kg/m^2 . However, the systematic overestimation by OLCI remains at 8%. The bias corrected *rmsd* is 0.9 kg/m².





Figure 55 OLCI IWV against ARM IWV retrievals for the SGP site (displayed in Figure 54).

Turner, D. D., Lesht, B. M., Clough, S. A., Liljegren, J. C., Revercomb, H. E., and Tobin, D. C.: Dry Bias and Variability in Vaisala RS80-H Radiosondes: The ARM Experience, J. Atmos. Ocean. Tech., 20, 117–132, doi:10.1175/15200426(2003)020<0117:DBAVIV>2.0.CO;2, 2003.

Turner, D. D., Clough, S. A., Liljegren, J. C., Clothiaux, E. E.,Cady-Pereira, K. E., and Gaustad, K. L.: Retrieving Liquid Water Path and Precipitable Water Vapor From the Atmospheric Radiation Measurement (ARM) Microwave Radiometers, IEEE T. Geosci. Remote Sens., 45, 3680– 3690,doi:10.1109/TGRS.2007.903703, 2007.



7 Level 2 SYN products validation

7.1 [SYN-L2-CV-100]

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



8 Events

Four OLCI Radiometric Calibration Sequences have been acquired during Cycle 029:

- So1 sequence (diffuser 1) on 12/03/2018 10:57 to 10:59 (absolute orbit 10761)
- So1 sequence (diffuser 1) on 22/03/2018 13:18 to 13:20 (absolute orbit 10905)
- S04 sequence (diffuser 1) on 31/03/2018 21:08 to 21:10 (absolute orbit 11038)
- S05 sequence (diffuser 2) on 31/03/2018 22:49 to 22:51 (absolute orbit 11039)

Two OLCI Spectral Calibration acquisitions have been acquired during Cycle 029:

- One S02/S03:
 - S02 sequence (diffuser 1) on 19/03/2018 11:15 to 11:16 (absolute orbit 10861)
 - S03 sequence (Erbium doped diffuser) on 19/03/2018 12:56 to 12:57 (absolute orbit 10862)
- And one S09 (Fraunhofer lines and oxygen absorption on Earth target):
 - S09 sequence on 19/03/2018 09:04:36 to 09:04:42 (absolute orbit 10860), for the first time with a duration reduced to 4.4 seconds (100 FR frames).



9 Appendix A

Other reports related to the Optical mission are:

S3-A SLSTR Cyclic Performance Report, Cycle No. 029 (ref. S3MPC.RAL.PR.02-029)

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

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