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

S3-A OLCI Cyclic Performance Report

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Changes Log

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1 Processing Baseline Version

IPF	IPF / Processing Baseline version	Date of deployment
OL1	06.08 / 2.38	CGS: 29/08/2018 09:24 UTC PAC: 29/08/2018 09:33 UTC
OL2	06.12 / 2.38	CGS: 29/08/2018 09:24 UTC PAC: 29/08/2018 09:33 UTC
SY2	06.14 / 2.39	PAC: 24/07/2018 07:12 UTC
SY2_VGS	06.06 / 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

Two OLCI Radiometric Calibration Sequences have been acquired during Cycle 038:

- So1 sequence (diffuser 1) on 22/11/2018 20:57 to 20:59 (absolute orbit 14403)
- S05 sequence (diffuser 2) on 22/11/2018 22:38 to 22:40 (absolute orbit 14404)

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. 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. 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.



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 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.

As there was no camera anomaly during the current cycle, there is no sudden change of periodic noise to report during the current cycle. However we notice that for camera 2 band Oa21 the PN phase seems to be drifting again since about orbit 13500. This drift shall be monitored carefully during the following months. Other bands/camera are more stable. The hot pixel impacting one of the "East blind pixels" for camera 4 smear band, presented in cycle #26 report, is still present and stable.

A new Calibration ADF has been delivered to MPC-CC for transfer to PDGS as part of Processing Baseline 2.42 (delivered on 23 NOV 2018). It includes an update of the Dark Offset and Dark Current LUTs. The updated LUTs are the one computed from radiometric sequence S01 of 5 NOV 2018.

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 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 86, one can see that Oa21 is by far the most affected, followed by the smear band (Figure 11, 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 11, right).



Figure 11: 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

Figure 12 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 12: 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 12, 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 13 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 13: 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 32 calibrations in extrapolation over about 16 months) remains better than 0.11% – except for channels Oa1 (400 nm), Oa2 (412.5 nm) and Oa21 (1020 nm) which are

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respectively < 0.29%, < 0.16% and < 0.17% – when averaged over the whole field of view (Figure 14) 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 15). Comparison of the two figures shows the improvement brought by the updated Model.



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



Figure 15: 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 16.



Figure 16: Camera-averaged instrument evolution since channel programming change (25/04/2016) and up to most recent calibration (22/11/2018) versus wavelength.

The overall per camera performance, as a function of wavelength, and at each orbit is shown on Figure 17 as the average and standard deviation of the model over data ratio.

Finally, Figure 18 to Figure 20 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 18 to Figure 20 with their counterparts in Report of Cycle 22 clearly demonstrate the improvement brought by the new model whatever the level of detail.



Figure 17: 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 32 calibrations in extrapolation, with a colour code for each calibration from blue (oldest) to red (most recent).

700 wavelength

600

500

14403

900

1000

1171

800

0.994

0.992

400



Figure 18: 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 32 calibrations in extrapolation, channels Oa1 to Oa6.





Figure 19: same as Figure 14 for channels Oa7 to Oa14.





Figure 20: same as Figure 18 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 038:

S05 sequence (diffuser 2) on 22/11/2018 22:38 to 22:40 (absolute orbit 14404)

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

S01 sequence (diffuser 1) on 22/11/2018 20:57 to 20:59 (absolute orbit 14403)

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 21 for band Oa01 and in Figure 22 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 21: diffuser 1 ageing for spectral band Oa01. We see strong ACT low frequency structures that are due to residual of BRDF modelling.



Figure 22: same as Figure 21 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 23.

Figure 21 and Figure 22 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 23 where we can see that this band is impacted by ageing of the diffuser.



Figure 23: same as Figure 21 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 24 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 24: Diffuser 1 ageing as a function of wavelength (or spectral band). Ageing is clearly visible in spectral band #1 to #5.

Figure 25 shows the evolution of the 5 camera averaged ageing as a function of time.



Figure 25: 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 26).



Figure 26: 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 26, we see that the Ageing slopes have not significantly changed between the current Cycle and the last four cycles with a S05 sequence (cycles #33, #29, #27, #24 and #20). Cycle #27 has been used to derive 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]

A new Calibration ADF has been delivered to MPC-CC for transfer to PDGS as part of Processing Baseline 2.42 (delivered on 23 NOV 2018):

S3A_OL_1_CAL_AX_20181105T213730_20991231T235959_20181122T120000_____MPC_O_AL_019.SEN3

It includes an update of the Dark Offset and Dark Current LUTs. The updated LUTs are the one computed from radiometric sequence S01 of 5 NOV 2018.

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 038 and results presented in Cycle 15 report are still valid.



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

There has been no Spectral Calibration (S02/S03, S09) acquisition during the reporting period.

Consequently, last results, presented in cycle 036 report are still valid.

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 27.

SNR computed for all calibration data as a function of orbit number for band OaO1 (the less stable band) is presented in Figure 28.

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



Figure 27: 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 28: 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: $SNR(L) = SNR(L_{ref})$

Following the same assumption, values at Full Resolution (300m) can be derived from RR ones as 4 times smaller.

 $\int \frac{L}{L_{ref}} \, .$



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	II
nm	LU	RQT	avg	std	avg	std	avg	std	avg	std	avg	std	avg	std
400.000	63.0	2188	2421	6.1	2398	6.6	2327	6.8	2376	11.7	2282	9.4	2361	7.0
412.000	74.1	2061	2393	8.2	2408	5.4	2340	4.6	2401	4.6	2384	7.5	2385	4.4
442.000	65.6	1811	2160	5.1	2199	5.7	2165	4.7	2185	4.1	2196	5.2	2181	3.4
490.000	51.2	1541	2000	4.7	2036	5.2	1996	3.9	1982	4.2	1988	4.8	2001	3.4
510.000	44.4	1488	1979	5.1	2014	4.9	1984	4.8	1966	4.7	1985	4.5	1986	3.8
560.000	31.5	1280	1776	4.4	1802	4.3	1802	4.8	1794	3.8	1818	3.5	1798	3.1
620.000	21.1	997	1591	4.3	1610	4.2	1624	3.2	1593	3.3	1615	3.6	1607	2.7
665.000	16.4	883	1546	4.3	1558	4.4	1567	3.8	1533	3.8	1560	3.8	1553	3.2
674.000	15.7	707	1329	3.4	1338	3.6	1350	2.8	1323	3.2	1342	3.7	1336	2.5
681.000	15.1	745	1319	3.7	1327	3.1	1337	2.8	1314	2.5	1333	3.6	1326	2.2
709.000	12.7	785	1420	4.6	1421	4.3	1435	3.5	1414	3.6	1430	3.2	1424	3.0
754.000	10.3	605	1127	3.3	1120	3.0	1135	3.6	1124	2.5	1139	3.0	1129	2.5
761.000	6.1	232	502	1.2	498	1.2	505	1.3	500	1.1	507	1.4	502	1.0
764.000	7.1	305	663	1.6	658	1.6	667	2.1	661	1.6	669	2.1	664	1.4
768.000	7.6	330	558	1.6	554	1.3	562	1.4	556	1.6	564	1.3	559	1.2
779.000	9.2	812	1515	5.0	1497	5.1	1524	5.4	1510	5.2	1525	4.9	1514	4.5
865.000	6.2	666	1244	3.6	1213	4.0	1238	4.2	1246	3.7	1250	2.9	1238	3.1
885.000	6.0	395	823	1.8	801	1.7	814	2.1	824	1.5	831	1.9	819	1.3
900.000	4.7	308	691	1.7	673	1.3	683	1.8	693	1.5	698	1.4	687	1.0
940.000	2.4	203	534	1.1	522	1.1	525	1.0	539	1.1	542	1.3	532	0.8
1020.000	3.9	152	345	0.8	337	0.9	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, the most dramatic improvements affecting along-track bias of Camera 3 (Figure 33) and across-track biases of Cameras 4 and 5 (Figure 34 & Figure 35, respectively). Cmpliance is comfortably met again (Figure 29): RMS values remain around 0.3 pixel and all biases below 0.2 pixel from 14/03 on, except for the along-track bias of camera 3 for which a small drift can be noticed, implying a performance slightly below -0.2 pixel since a few weeks.(Figure 33, right).

It can be seen that the peak RMS value on 14/08/2018 is associated to a very low number of GCPs: only 345 (out of scale on Figure 30) and can be considered as an outlier. The same remark applies to the AC and AL biases displayed in Figure 31 to Figure 35.



Figure 29: overall OLCI georeferencing RMS performance time series over the whole monitoring period (left) and restricted to March 2018 on (right)



Figure 30: number of validated control points corresponding to the performance time series of Figure 29 for the same periods (complete, left, and restricted to March 2018, right).



Figure 31: across-track (left) and along-track (right) georeferencing biases time series for Camera 1 (starting 01/03/2018).



Figure 32: same as Figure 31 for Camera 2.





Figure 35: same as Figure 31 for Camera 5.



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).



Figure 36: 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

S3A/OLCI L1B radiometry verification as follow:

- The verification is performed until 6th December 2018 and 20th November 2018 depending on method.
- All results over 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 slightly higher reflectance over the VNIR spectral range with bias of 2%-4% except bands Oa06-Oa09 and Oa16-Oa17.
- Bands with high gaseous absorption are excluded.



I-Validation over PICS

- 1. Ingestion of all the available L1B-LN1-NT products in the S3A-Opt database over the 6 desert calvalsites (Algeria3 & 5, Libya 1 & 4 and Mauritania 1 & 2) has been performed until 6th December 2018.
- 2. The results are consistent overall the six used PICS sites (Figure 37). OLCI-A reflectance shows a good stability over the analysed period.
- 3. The temporal average over the period January 2018 December 2018 of the elementary ratios (observed reflectance to the simulated one) shows values better than/around 3-4% over all the VNIR bands, while bands Oa06-Oa09 and Oa16-Oa17 display biases within the 2% (the mission requirement) (Figure 38). The spectral bands with significant absorption from water vapor and O₂ (Oa11, Oa13, Oa14 and Oa15) are excluded.





Figure 37: Time-series of the elementary ratios (observed/simulated) signal from S3A/OLCI for (top to bottom) bands Oa08 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 38: The estimated gain values for S3A/OLCI over the 6 PICS sites identified by CEOS over the period January – December 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 September and November 2018 respectively. Figure 39 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 November 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 40 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 40) than the other sensors, which means that OLCI-A has higher reflectance that the ones simulated by the PICS method.





Figure 39: 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. The uncertainty of desert methodology is 5%.





Figure 40: 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 from January to December 2018. The results are produced with the configuration (ROI-AVERAGE). The gain coefficients are consistent with the previous results (Cycle-37). Bands Oa01-Oa05 display biases values between 4%-5% while bands Oa6-Oa9 exhibit biases between 3%-4% higher than the 2% mission requirements (Figure 41 and Figure 42).



Figure 41: 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 April 2016 – October 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

0.90

0.85 400

450

Glint calibration method with the configuration (ROI-PIXEL) has been performed over the period January - December 2018, as for the Rayleigh method (above). The outcome of this analysis shows a good consistency with the desert outputs over the NIR spectral range Oa06-Oa09. Glint results show that the VNIR bands are within the 2% mission requirements, except Oa5 and Oa21 which show biases of ~3% and ~7% respectively (see Figure 42).



Figure 42: The estimated gain values for S3A/OLCI from Glint, Rayleigh and PICS over the period January – December 2018 for Desert, Glint and Rayleigh methods as a function of wavelength. We use the gain value of Oa8 from Desert method as reference gain for Glint. Dashed-green and orange lines indicate the 2% and 5% respectively. Error bars indicate the methods uncertainties.



3.1.3 Radiometric validation with OSCAR

The OSCAR Rayleigh have been applied to all S3ETRAC data acquired over the period June-Oct 2018.

The average OSCAR Rayleigh results and the standard deviation calibration are shown below (Figure 43). Results are in line with previously reported results.



Figure 43. OSCAR Rayleigh S3A Calibration results: weighted average over all sites and standard deviation for September 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.



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4 Level 2 Land products validation

4.1 [OLCI-L2LRF-CV-300]

4.1.1 Routine extractions

Activities done

- The focus for this time period has been on the rolling archive Near Real Time Critical (NT) data until 09/11/2018.
- Concatenated time series of OLCI Global Vegetation Index and OLCI Terrestrial Chlorophyll Index have been generated on the current rolling archive and including previous extractions since April 2018. The time series therefore represent the whole mission duration.

Figure 44 to Figure 53 below present the Core Land Sites OLCI time series over the Sentinel3-A/OLCI mission.



Figure 44: DeGeb time series over current reporting period



Figure 46: ITsp time series over current reporting period

Figure 45: ITCat time series over current reporting period



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Figure 47: ITSro time series over current reporting period



Figure 48: ITTra time series over current reporting period



Figure 49: SPAli time series over current reporting period







Figure 51: USNe1 time series over current reporting period



Figure 52: USNe2 time series over current reporting period



Figure 53: USNe3 time series over current reporting period

4.1.2 Comparisons with MERIS MGVI and MTCI climatology

The present report provides results on the performance of OLCI OGVI and OTCI for a total of 27 sites, seven of those correspond to ESA Core Sites and the rest to the Land Product Validation (LPV) Subgroup sites. The Core sites located in Europe comprise cropland, deciduous forest and mixed forest whereas LPV sites are scattered across the globe and include a variety of land cover types (see Table 2). The following time-series plots show the Medium Resolution Imaging Spectrometer (MERIS) Climatology trend ± 1 standard deviation (SD). The blue points represent the three by three pixel average of pixel extractions for each site. The red points correspond to the present cycle.

Overall both, OGVI and OTCI follow the general climatology trend and the local temporal pattern. However, some sites present slight deviations and systematic over or underestimations. For instance, sites such as FR-Aurade, IT-Cat, AU-Great-Western, FR-Guayaflux, and PR-Guanica, present systematic overestimation for OGVI (Figure 55, Figure 56, Figure 73, Figure 77 and Figure 78). On the contrary, sites such as IT-Cat, UK-NFo and FR-Guayaflux, present systematic underestimation for OTCI (Figure 56, Figure 62 and Figure 77). For site SE-Dahra, it seems the initiation shifted to later dates (Figure 61). This pattern appears more evident for OGVI. The systematic over and underestimations, along with shifts in patterns are being investigated.

Table 2: Land Product Validation su	persites and Core sites descr	iption included in the current report.

Acronym	Country	Ν	letwork	Lat	Lon	Land cover
DE-Geb	Deutschland	CORE		51.1	10.914 Cropland	
FR-Aurade	France	ICOS		43.55	1.106 Cropland	
IT-Cat	Italy	CORE	:	37.279	14.883 Cropland	
IT-Lison	Italy	ICOS		45.74	12.75 Cropland	



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IT-Tra	Italy	CORE	37.646	12.867 Cropland
SP-Ali	Spain	CORE	38.452	-1.065 Cropland
FR-Estrees-Mons	France	ICOS Associated	49.872	3.021 Cultivated and managed areas
SE-Dahra	Senegal	KIT / UC	15.4	-15.43 Cultivated and managed areas
UK-NFo	United Kingdom	CORE	50.845	-1.54 Deciduous forest
IT-lsp	Italy	CORE	45.813	8.635 Mixed forest
IT-Sro	Italy	CORE	43.728	10.284 Mixed forest
AU-Calperum	Australia	TERN-SuperSites, AusCover/OzFlux	-34.003	140.588 Shrub Cover, closed-open, deciduous
US-Central-Plains	United States	NEON, AERONET	40.816	-104.746 Shrub Cover, closed-open, deciduous
US-Jornada	United States	LTER	32.591	-106.843 Shrub Cover, closed-open, deciduous
DE-Hones-Holz	Deutschland	ICOS	52.085	11.222 Tree Cover, broadleaved, deciduous, closed
FR-Hesse	France	ICOS	48.674	7.065 Tree Cover, broadleaved, deciduous, closed
IT-Collelongo	Italy	EFDC	41.849	13.588 Tree Cover, broadleaved, deciduous, closed
US-Bartlett	United States	NEON, AERONET	44.064	-71.287 Tree Cover, broadleaved, deciduous, closed
US-Harvard	United States	NEON, AERONET	42.537	-72.173 Tree Cover, broadleaved, deciduous, closed
AU-Great-Western	Australia	TERN-SuperSites, AusCover/OzFlux	-30.192	120.654 Tree Cover, broadleaved, deciduous, open
AU-Cape-Tribulation	Australia	TERN-SuperSites, OzFlux	-16.106	145.378 Tree Cover, broadleaved, evergreen
AU-Cumberland	Australia	TERN-SuperSites, AusCover/OzFlux	-33.615	150.723 Tree Cover, broadleaved, evergreen
AU-Litchfield	Australia	TERN-SuperSites, AusCover/OzFlux	-13.18	130.79 Tree Cover, broadleaved, evergreen
FR-Guayaflux	France	ICOS Associated	5.279	-52.925 Tree Cover, broadleaved, evergreen
PR-Guanica	Puerto Rico	NEON	17.97	-66.869 Tree Cover, broadleaved, evergreen
AU-Alice-Mulga	Australia	TERN-SuperSites, AusCover/OzFlux	-22.283	133.251 Tree Cover, closed (76% cover), evergreen
BE-Brasschaat	Belgium	ICOS	51.308	4.52 Tree Cover, needle-leaved, evergreen





Figure 54: On the left, time-series of OGVI and OTCI for site DE-Geb, Deutschland, land cover Cropland. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 55: On the left, time-series of OGVI and OTCI for site FR-Aurade, France, land cover Cropland. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 56: On the left, time-series of OGVI and OTCI for site IT-Cat, Italy, land cover Cropland. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 57: On the left, time-series of OGVI and OTCI for site IT-Lison, Italy, land cover Cropland. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 58: On the left, time-series of OGVI and OTCI for site IT-Tra, Italy, land cover Cropland. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 59: On the left, time-series of OGVI and OTCI for site SP-Ali, Spain, land cover Cropland. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 60: On the left, time-series of OGVI and OTCI for site FR-Estrees-Mons, France, land cover Cultivated and managed areas. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively. Figure 7





Figure 61: On the left, time-series of OGVI and OTCI for site SE-Dahra, Senegal, land cover Cultivated and managed areas. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively. Figure 8





Figure 62: On the left, time-series of OGVI and OTCI for site UK-NFo, United Kingdom, land cover Deciduous forest. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively. Figure 9





Figure 63: On the left, time-series of OGVI and OTCI for site IT-Isp, Italy, land cover Mixed forest. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 64: On the left, time-series of OGVI and OTCI for site IT-Sro, Italy, land cover Mixed forest. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 65: On the left, time-series of OGVI and OTCI for site AU-Calperum, Australia, land cover Shrub Cover, closed-open, deciduous. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 66: On the left, time-series of OGVI and OTCI for site US-Central-Plains, United States, land cover Shrub Cover, closed-open, deciduous. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 67: On the left, time-series of OGVI and OTCI for site US-Jornada, United States, land cover Shrub Cover, closed-open, deciduous. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 68: On the left, time-series of OGVI and OTCI for site DE-Hones-Holz, Deutschland, land cover Tree Cover, broadleaved, deciduous, closed. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 69: On the left, time-series of OGVI and OTCI for site FR-Hesse, France, land cover Tree Cover, broadleaved, deciduous, closed. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 70: On the left, time-series of OGVI and OTCI for site IT-Collelongo, Italy, land cover Tree Cover, broadleaved, deciduous, closed. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.




Figure 71: On the left, time-series of OGVI and OTCI for site US-Bartlett, United States, land cover Tree Cover, broadleaved, deciduous, closed. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 72: On the left, time-series of OGVI and OTCI for site US-Harvard, United States, land cover Tree Cover, broadleaved, deciduous, closed. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 73: On the left, time-series of OGVI and OTCI for site AU-Great-Western, Australia, land cover Tree Cover, broadleaved, deciduous, open. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 74: On the left, time-series of OGVI and OTCI for site AU-Cape-Tribulation, Australia, land cover Tree Cover, broadleaved, evergreen. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 75: On the left, time-series of OGVI and OTCI for site AU-Cumberland, Australia, land cover Tree Cover, broadleaved, evergreen. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 76: On the left, time-series of OGVI and OTCI for site AU-Litchfield, Australia, land cover Tree Cover, broadleaved, evergreen. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 77: On the left, time-series of OGVI and OTCI for site FR-Guayaflux, France, land cover Tree Cover, broadleaved, evergreen. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 78: On the left, time-series of OGVI and OTCI for site PR-Guanica, Puerto Rico, land cover Tree Cover, broadleaved, evergreen. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 79: On the left, time-series of OGVI and OTCI for site AU-Alice-Mulga, Australia, land cover Tree Cover, closed (76% cover), evergreen. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.





Figure 80: On the left, time-series of OGVI and OTCI for site BE-Brasschaat, Belgium, land cover Tree Cover, needle-leaved, evergreen. On the right, scatterplot of monthly OGVI and OTCI against MGVI and MTCI, respectively.

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 038. 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 until December the 12th.
- Current reporting period is her after compared to the reprocessed archive covering the April 2016 to November 2017 period. No issue is 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 extractions since July 2017. The available matchups therefore represent over one year of operation.
- At best 196 and 199 matchups at 490 and 560nm respectively are useful for this time period. OLCI's performances remain nominal.

Overall Water-leaving Reflectance performance

Figure 81 and Figure 82 below presents 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 (July 2017 to December 2018).

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

Table 3 and Table 4 below summarise the statistics over reprocessed time period and the current reporting period, respectively. Some statistical variables can differ very much as a consequence of the little number of points (ex: slope and intercept). Nonetheless RMSE are in the same order of magnitude for both dataset.





Figure 81: Scatter plots of OLCI versus in situ radiometry (FR data). Reprocessed dataset (left), all available data for the current time period (right), channels Oa1 to Oa4.





Figure 82: Scatter plots of OLCI versus in situ radiometry (FR data). Reprocessed dataset (left), all available data for the current time period (right), channels Oa5, Oa6 and Oa8

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Table 3: FR statistics over REP_006 period; FR data.

lambda	N	RPD	RPD	MAD	RMSE	slope	intercept	r2
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 4: FR statistics over July 2017 to December 2018, cycles 20 to 38; FR data.

lambda	Ν	RPD	RPD	MAD	RMSE	slope	intercept	r2
400	40	-4.27%	8.09%	-0.0022	0.0047	0.9083	0.0020	0.5957
412	96	7.29%	37.76%	-0.0019	0.0052	0.8760	0.0010	0.9223
443	123	-0.19%	24.53%	-0.0014	0.0037	0.8785	0.0007	0.9024
490	196	-6.50%	17.36%	-0.0012	0.0029	0.9064	0.0001	0.7156
510	103	-8.55%	13.93%	-0.0013	0.0026	0.7714	0.0015	0.7177
560	199	-4.41%	15.68%	-0.0007	0.0022	0.8628	0.0006	0.8660
665	39	-21.41%	33.31%	-0.0007	0.0010	0.6098	0.0004	0.6456

Time series

Figure 83 and Figure 84 below present AAOT and MOBY in situ and OLCI time series over the current reporting period.



Figure 83: AAOT time series over current reporting period





Figure 84: MOBY time series over current reporting 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

Activities done

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. Only quality assured L2 data is used. Herein we limit to data after Nov 2017 (processing baseline > v2.23) and non-time-critical full-resolution data (*wfr NT*). Up to now 5000 co-locations with AERONET stations or available maritime AERONET cruises 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 85. The linear correlation of the aerosol optical thickness at 865nm is about 0.4 (mainly due to two outliers), with a systematic bias of around 0.04. The bias corrected root mean squared distance is 0.09. 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 correlation; we found 0.44.







Figure 85: Left: OLCI aerosol optical thickness at 865nm against AERONET optical thickness at 870nm, right: OLCIs Angstroem exponent at 865nm-779nm against the Aeronet Angstrom exponent at 865nm-440nm. The error-bars represent the standard deviation within the 10x10km² OLCI scene, and the uncertainty of the AERONET product, respectively. The data covers the period from November 2017 – October 2018. The geographic location of the AERONET stations is shown in the top (red spots have been used, green spots have been filtered)







Figure 86: Left: OLCI aerosol optical thickness at 865nm against maritime Aeronet aerosol network optical thickness at 870nm, right: OLCIs Angstroem exponent at 865nm-779nm against the maritime Aeronet Angstroem exponent at 865nm-440nm. The error-bars represent the standard deviation within the 10x10km² OLCI scene, and the uncertainty of the AERONET product, respectively. The data covers the period from November 2017- October 2018. The geographic location of the co-located ship cruises is shown in the top (red spots have been used, green spots have been filtered)

The 370 MAN co-locations, acquired during ship cruises, evolved to 36 valid matchups, shown in Figure 86. Here the agreement of the aerosol optical thickness at 865nm is better than for the AERONET/AERONET-OC comparisons, the linear correlation is 0.78. A small (0.02) positive bias is found and the root mean squared distance is 0.05. The not-directly comparable Angstrom coefficients don't show a significant correlation and a root mean squared distance of 0.46.

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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.



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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 vapour from AERONET (Pérez-Ramírez et al 2014, Holben et al 1998) and water vapour 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) and Marine AERONET (Smirnov et al 2009) data. Further island and coastal AERONET and GNSS data has been used.

6.2 Quantitative validation using GNSS - Land

The OLCI IWV above land surface product is continuously validated via global GNSS (Ware et al. 2000) measurements. 16000 matchups within the period of November 2017 (new processing baseline, with an improved cloud mask) to October 2018 have been analysed. The scenes cover high and low elevations, however, the majority of the used SUOMI-NET ground stations are in North and Central America. Only OLCI measurements are taken for the validation which are above land and are cloud-free in an area of about 30 km around the GNSS stations. For the cloud detection, the standard L2 cloud-mask has been applied (including the cloud ambiguous and cloud margin flags).



Figure 87: Position of the GNSS stations used for the IWV validation. Light green dots indicate positions which haven't been used, because of cloud contaminations.

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The validation of the IWV product shows a high agreement between the OLCI and the GNSS derived IWV (Figure 88). The correlation between both quantities is 0.98. The root-mean-squared-difference (rmsd) is 3 kg/m². However, there is a systematic overestimation of 14%, which leads to a wet bias of 1.9 kg/m². The bias corrected rmsd is 1.6 kg/m².



Figure 88: Scatter plot of the IWV products, derived from OLCI above land and from GNSS measurements.

The wet bias of OLCI might indicate an insufficient description of the measurements within the retrieval. The reasons could be either insufficient description of the instrument, or of the radiative transfer, in particular the absorption of atmospheric water vapour.

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. This may lead to a slight wet bias of the OLCI estimation.

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600 matchups within the period of November 2017 to October 2018 have been analysed. The scenes cover mostly coastal zones. Only OLCI measurements are taken for the validation which are above water surfaces and are cloud-free in an area of about 30 km around the GNSS stations. For the cloud detection, the standard L2 cloud-mask has been applied (including the cloud ambiguous and cloud margin flags).



Figure 89: Position of the GNSS stations used for the IWV validation above water surfaces. Light green dots indicate positions, which haven't been used.

As expected from the visual inspection, we see a large number of wet outliers leading to a large systematic error of 7 kg/m^2 and a root mean squared difference of 11 kg/m^2 .

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Figure 90: Scatter plot of the IWV products, derived from OLCI above water and from GNSS measurements.

6.4 Quantitative validation using AERONET IWV Retrievals – Land

A further step in the validation process is realised by using IWV, derived from spectral AERONET measurements. The used AERONET match-ups are displayed in Figure 91. Solely *level2* products have been used which are cloud screened and quality assured.





Figure 91: Position of the AERONET stations used for the IWV validation. Green dots indicate filtered (not used) matchups.

The comparison of the IWV AERONET product shows a high agreement with the OLCI IWV product (Figure 92). The correlation between both quantities is 0.98. The root-mean-squared-difference is 4 kg/m². However, there is a systematic overestimation by OLCI of 20% and a bias of 2.3 kg/m². The bias corrected *rmsd* is 1.8 kg/m², in agreement with the GNSS assessment.





Figure 92: OLCI IWV above land against AERONET IWV retrievals for the sites displayed in Figure 91.

6.5 Validation by AERONET IWV Retrievals - Ocean

Selected maritime AERONET cruises have been used to further inspect the quality of the OLCI IWV above ocean. The position of the cruises are displayed in Figure 93.



Figure 93: Position of the MAN cruises used for the IWV validation. (Green dots indicate cloud contaminations)

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The comparison shows a weak agreement (figure 12), in accordance with the GNSS comparisons. The correlation is 0.6. The root-mean-squared-difference is 12 kg/m^2 , the bias is 9 kg/m^2 . Even though the number of data points is low (18 data points only), the general findings are as in the previous investigations.





6.6 Quantitative validation using ARM MWR IWV Retrievals – Land

Another alternative for the IWV validation is realised by using IWV derived from ground based microwave radiometer measurements. Currently 3 ARM sites are operated continuously, two of them over land (Figure 95).





Figure 95: Position of the ARM stations used for the IWV validation. Currently only at the SGP site (southern great planes) and NSA (north slope Alaska) have been found.

The comparison of OLCI and ARM shows an almost perfect agreement (Figure 96). The correlation between both quantities is 0.99 The root-mean-squared-difference is 1.7 kg/m^2 . However, the systematic overestimation by OLCI remains at 9%. The bias corrected *rmsd* is 1.0 kg/m^2 .



Figure 96 OLCI IWV against ARM IWV retrievals for the SGP site (displayed in Figure 95).



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6.7 Summary

- The validation exercise of the OLCI IWV product has been successful. It demonstrates that the product is of high quality for retrievals above land surfaces. But there is a systematic overestimation of 9%, 14% to 20%, depending on 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 10%. Further, we know, that SUOMI-GNSS has a dry-bias of 3% with respect to ARM measurements (see Figure 97), which is 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. 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 97 : ARM vs. GNSS IWV retrievals for the SGP site (Figure 95) for the period Nov 2017- 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

7.1 [SYN-L2-CV-100]

Recall of the Cal/Val plan methodology:

- The methodology consists in extracting the L2 SYN product in windows centered over AERONET test sites representing a large diversity of aerosol model, aerosol load and surface type, compare AOT retrieved from Aeronet and SYN2 data, and finally compare atmospherically corrected reflectance using Aeronet information and SYN 2 Surface Directional Reflectances.
- The tools needed are nominally, OLCI L1 and L2 SYN product extraction tool providing (~50x50 km) macro pixels around the Aeronet sites preferably with the possibility to generate breakpoint outputs of the SYN algorithm, and raw analysis tools such as regression and statistics tool.

• Summary of activities

The dataset of one week L2 SYN Global orbit products was downloaded from S3MPC ftp on November 1st 2018; directory : `Reprocessed_week_PB_2.40'. It was generated using the same level 1 data used last year for the first L2 SYN dataset evaluation ('TDS_IPF_PB2.26'). remarks concerning the dataset itself:

- 1. Large data volume to handle (still no child product)
- 2. Matchups with AERONET has to be done by ESL
- 3. No link with L1 OLCI and L1 SLSTR, difficulties to perform atmospheric correction, i.e. the key point to validate the surface reflectance SYN product
- 4. Image reading : Difficulty to open data SYN2 file with SNAP (~ 10 minutes, with SNAP 6.0)

We checked the flags combination to obtain 'good' quality AOT products and verify that the bets results were obtained for the combination:

!SYN.CLOUD & !SYN.PARTLY_CLOUDY & SYN.SUCCESS & !SYN.TOO_LOW & !SYN.HIGH_ERROR & !SYN.NEGATIVE_CURVATURE & !SYN.AEROSOL_FILLED & !SYN.NO SLO & !SYN.NO SLN & !SYN.NO OLC.

The AOT images inspection and Surface Directional Reflectance images show slight changes between processing version, but without clear evidences that the new one improves the quality of the results.

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The number of matchups with Aeronet AOD has been extended to 511 since last validation exercise.

The improvement between processing versions is limited (See Figure 98), and the AOT product is likely still largely contaminated by clouds, however a slight improvement can be noticed through a reduction of the positive biases by about 10%.



Figure 98 : Regression between L2 SYN AOD and Aeronet AOD at 550 nm during one week in November 2016. (Top) using the processing PB2.26; (Bottom) last reprocessing PB2.40. From left to right the matchups are obtained for L2SYN 9x9, 3x3 and 1x1 pixels boxes respectively. The flag combination for matchups filtering was the most conservative one (see text)



8 Events

Two OLCI Radiometric Calibration Sequences have been acquired during Cycle 038:

- So1 sequence (diffuser 1) on 22/11/2018 20:57 to 20:59 (absolute orbit 14403)
- S05 sequence (diffuser 2) on 22/11/2018 22:38 to 22:40 (absolute orbit 14404)



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9 Appendix A

Other reports related to the Optical mission are:

S3-A SLSTR Cyclic Performance Report, Cycle No. 038 (ref. S3MPC.RAL.PR.02-038)

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

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