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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1 Processing Baseline Version

IPF	IPF / Processing Baseline version	Date of deployment
OL1	06.07 / 2.23	CGS: 05/07/2017 13:00 UTC (NRT)
		PAC: 05/07/2017 12:50 UTC (NTC)
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.

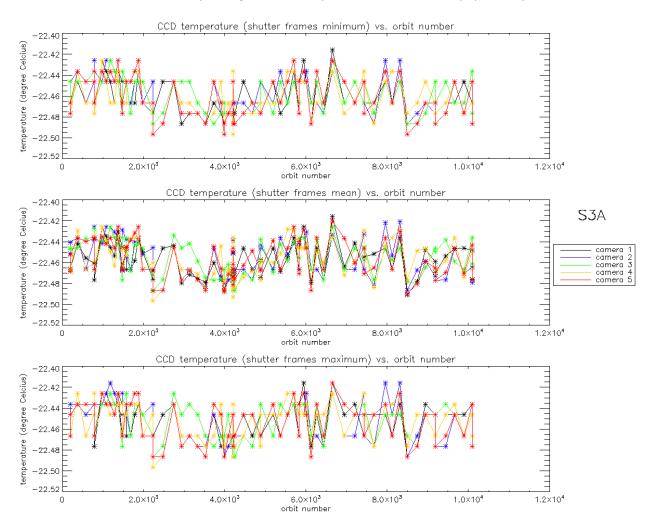


Figure 1: long term monitoring of CCD temperatures using minimum value (top), time averaged values (middle), and maximum value (bottom) provided in the annotations of the Radiometric Calibration Level 1 products, for the Shutter frames, all radiometric calibrations so far.



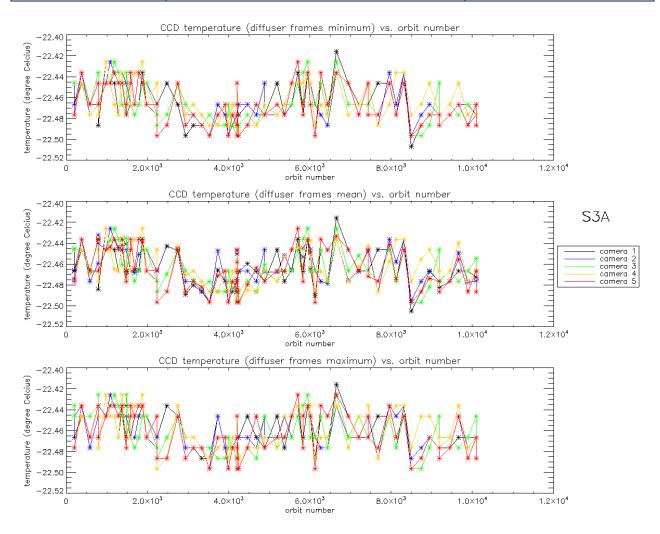


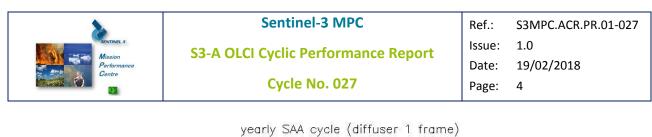
Figure 2: Same as Figure 1 for diffuser frames.

2.2 Radiometric Calibration

Two OLCI Radiometric Calibration Sequences have been acquired during Cycle 027:

- S04 sequence (diffuser 1) on 25/01/2018 04:11 to 04:13 (absolute orbit 10101)
- S05 sequence (diffuser 2) on 25/01/2018 05:52 to 05:54 (absolute orbit 10102)

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



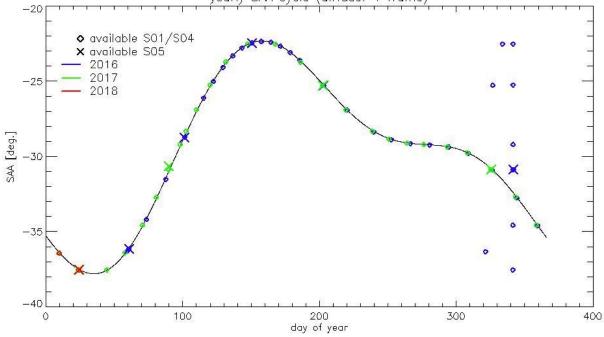


Figure 3: Sun azimuth angles during acquired Radiometric Calibrations (diffuser frame) on top of nominal yearly cycle (black curve). Diffuser 1 with diamonds, diffuser 2 with crosses, 2016 acquisitions in blue, 2017 in green, 2018 in red.

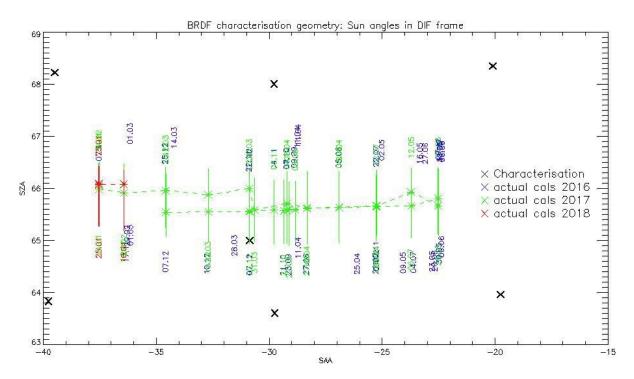


Figure 4: Sun geometry during radiometric Calibrations on top of characterization ones (diffuser frame)

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.

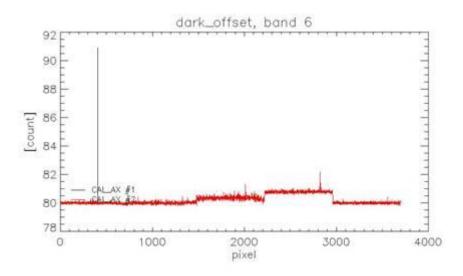


Figure 5: Dark Offset table for band Oa06 with (red) and without (black) HEP filtering (Radiometric Calibration of 22 July 2017). The strong HEP event near pixel 400 has been detected and removed by the HEP filtering.

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.

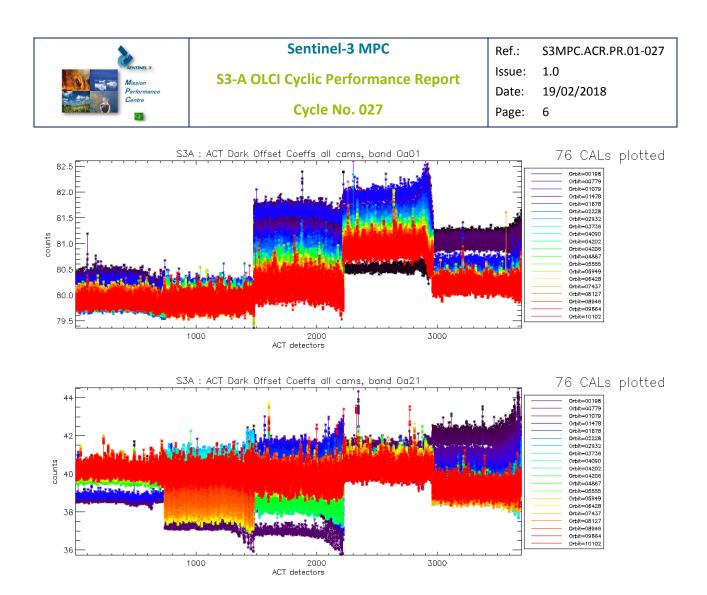


Figure 6: Dark Offset for band Oa1 (top) and Oa21 (bottom), all radiometric calibrations so far except the first one (orbit 183) for which the instrument was not thermally stable yet.

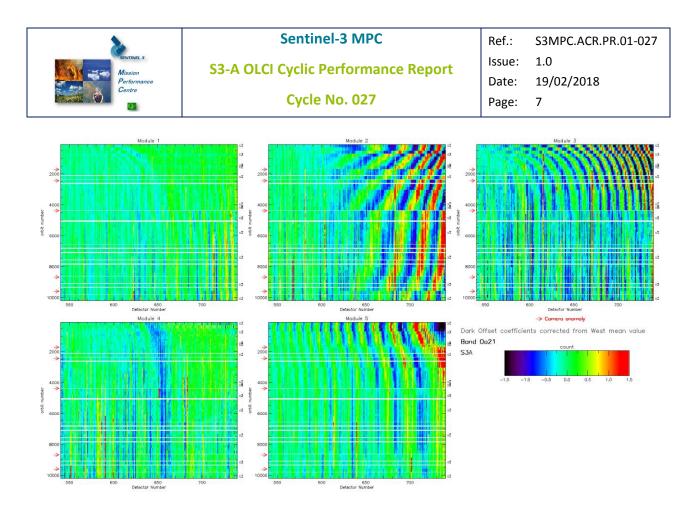


Figure 7: map of periodic noise for the 5 cameras, for band Oa21. X-axis is detector number (East part, from 540 to 740, where the periodic noise occurs), Y-axis is the orbit number. The counts have been corrected from the west detectors mean value (not affected by periodic noise) in order to remove 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.

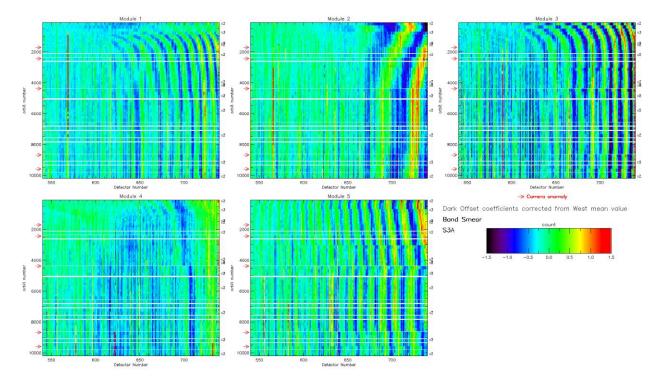


Figure 8: same as Figure 7 for smear band.

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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.

Consequently, based on the results presented in figure 7, 8, 9 and 10 of cyclic report #26, we recommend that the CAL_AX used in PDGS is updated, as soon as possible, with a dark offset table and a dark current table computed from a Calibration sequence posterior to the December 2017-anomaly. This will be implemented at the next PB update (foreseen in Mid February).

Dark Currents

Dark Currents 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.

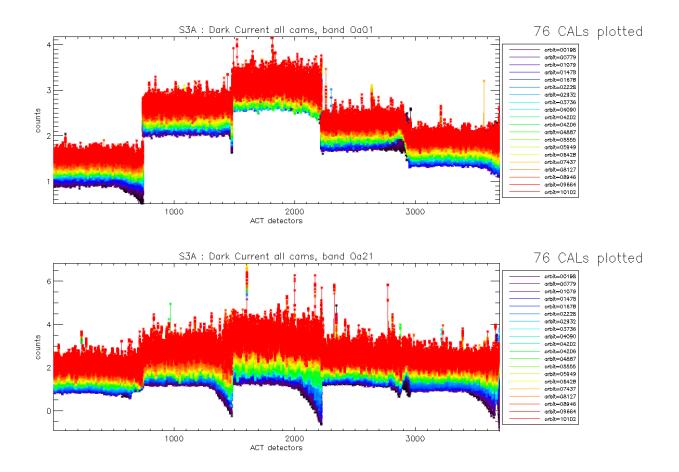




Figure 9: Dark Current for band Oa1 (top) and Oa21 (bottom), all radiometric calibrations so far except the first one (orbit 183) for which the instrument was not thermally stable yet.

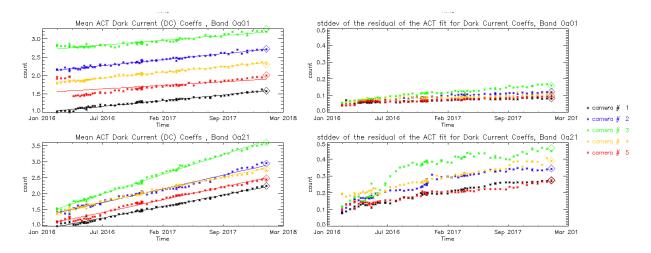


Figure 10: left column: ACT mean on 400 first detectors of Dark Current coefficients for spectral band Oa01 (top) and Oa21 (bottom). Right column: same as left column but for Standard deviation instead of mean. We see an increase of the DC level as a function of time especially for band Oa21. A possible 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 below 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.



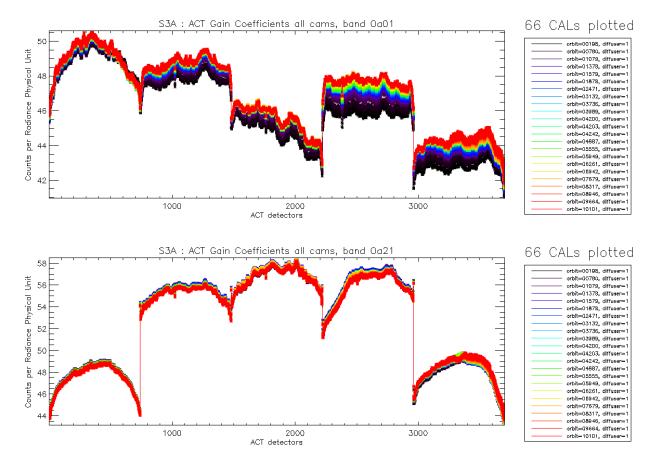


Figure 11: Gain Coefficients for band Oa1 (top) and Oa21 (bottom), all diffuser 1 radiometric calibrations so far except the first one (orbit 183) for which the instrument was not thermally stable yet.

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 is plotted as a function of time, for each module, relative to a given reference calibration (the 12/11/2016). 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.



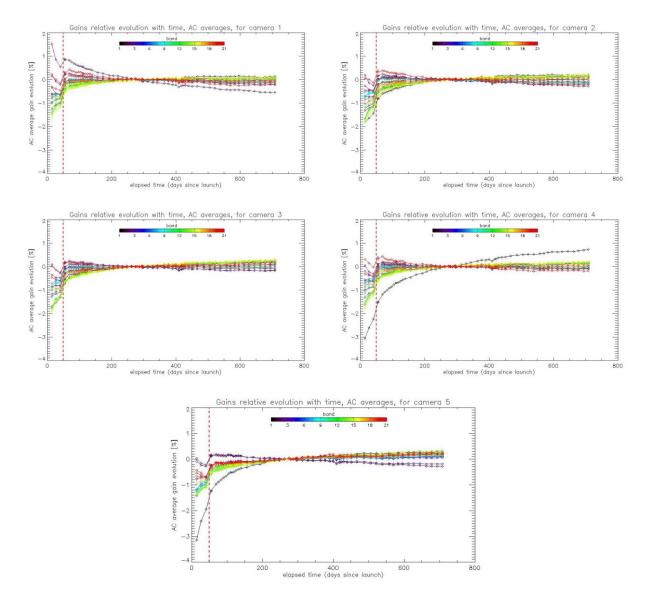


Figure 12: camera averaged gain relative evolution with respect to "best geometry" calibration (22/11/2016), as a function of elapsed time since launch; one curve for each band (see colour code on plots), one plot for each module. The star tracker anomaly fix (6/04/16) is represented by a vertical red dashed line.

The behaviour over the first two months of mission, really different and highlighted by Figure 12, is explained by the Star Tracker software anomaly during which the attitude information provided by the platform was corrupted, preventing to compute a correct illumination geometry, with a significant impact on the gain computation.

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 26/04/2016 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

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the complete dataset (including the 10 calibrations in extrapolation over about five months) remains better than 0.1% – except for channels Oa1 (400nm) and Oa21 (1020 nm), at about 0.13% – 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.

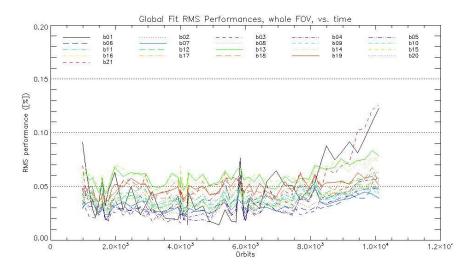


Figure 13: RMS performance of the Gain Model of current Processing Baseline as a function of orbit.

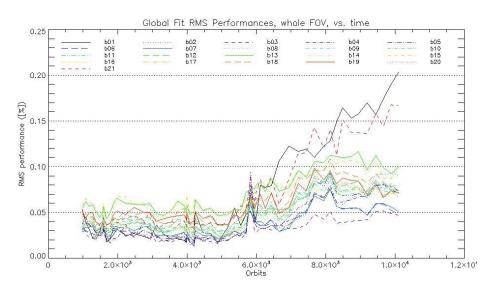


Figure 14: RMS performance of the Gain Model of previous Processing Baseline as a function of orbit.

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



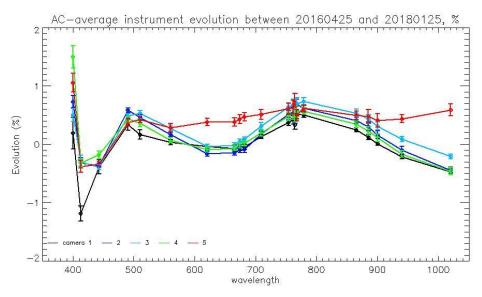


Figure 15: Camera-averaged instrument evolution since channel programming change (25/04/2016) and up to most recent calibration (25/01/2018) versus wavelength.

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

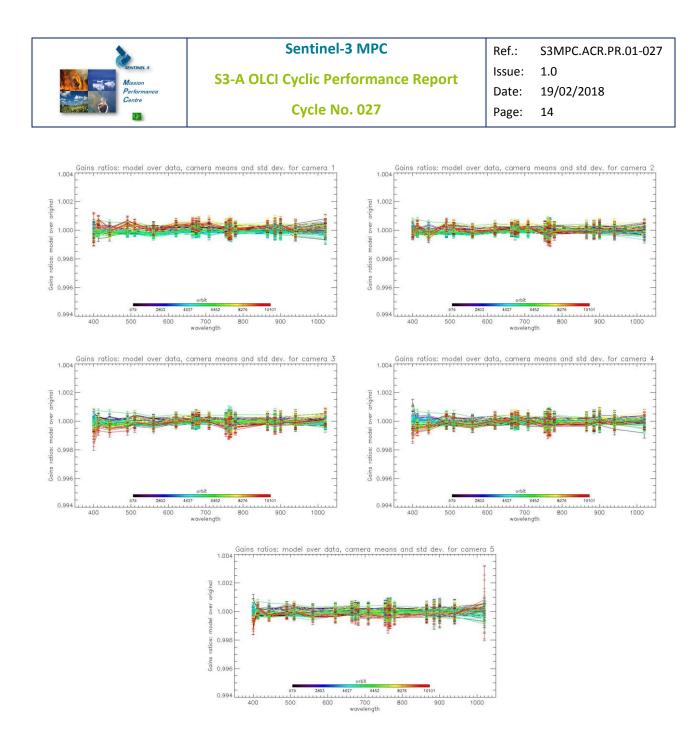


Figure 16: For the 5 cameras: Evolution model performance, as camera-average and standard deviation of ratio of Model over Data vs. wavelength, for each orbit of the test dataset, including 10 calibrations in extrapolation, with a colour code for each calibration from blue (oldest) to red (most recent).

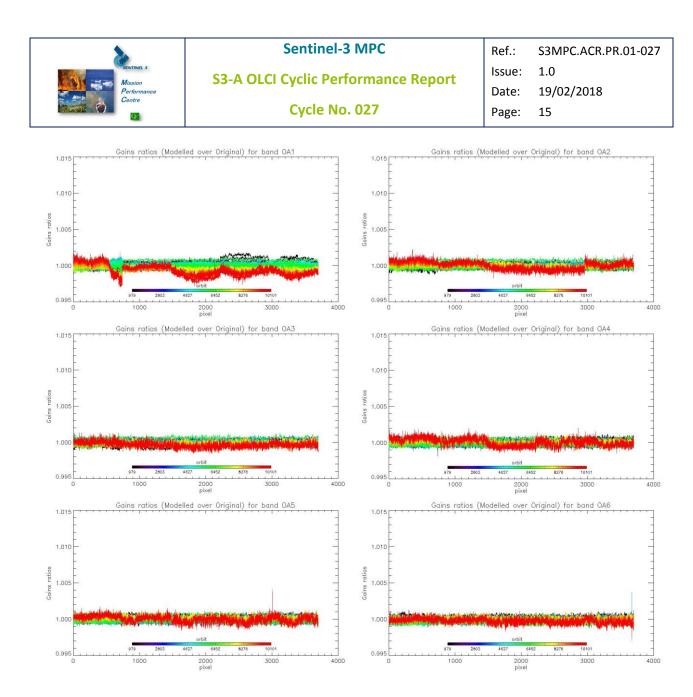


Figure 17: Evolution model performance, as ratio of Model over Data vs. pixels, all cameras side by side, over the whole current calibration dataset (since instrument programing update), including 10 calibrations in extrapolation, channels Oa1 to Oa6.

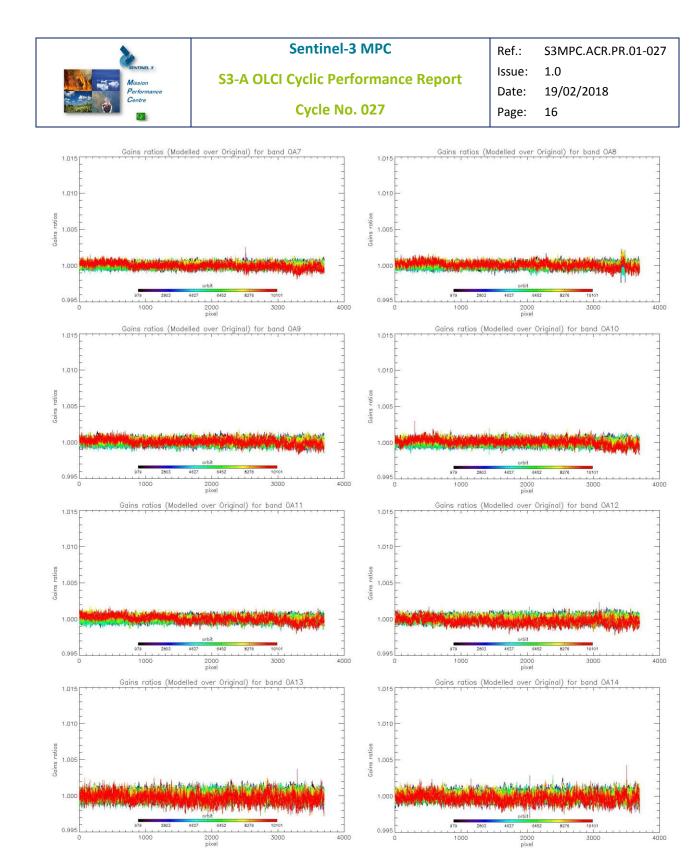
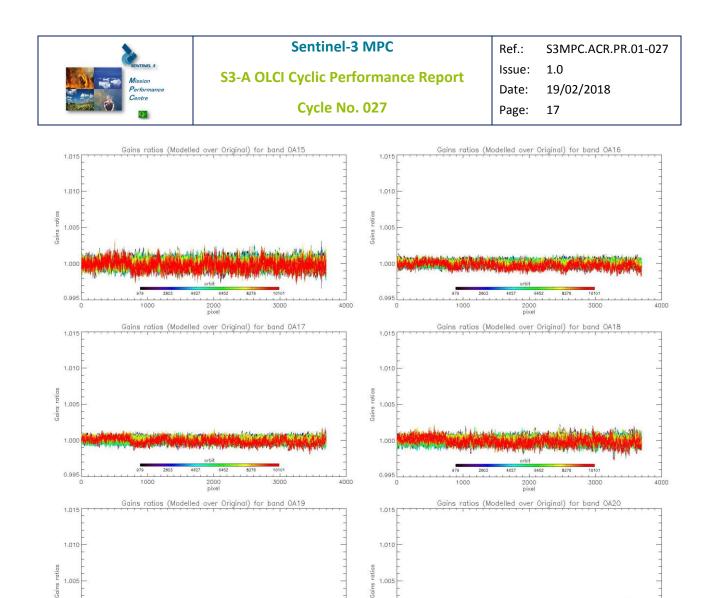
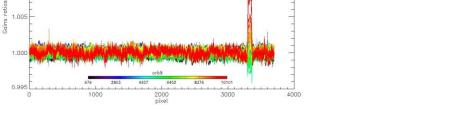


Figure 18: same as Figure 14 for channels Oa7 to Oa14.





3000

1.005

1.000

0.995

1.015

1.010

1000

2000 pixel

Gains ratios (Modelled over Original) for band OA21

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

1.005 Gains

1.000

0.995

1000

2000 pixel

3000

4000

4000

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

There has been one calibration sequence S05 (reference diffuser) acquisition during cycle 027:

S05 sequence (diffuser 2) on 25/01/2018 05:52 to 05:54 (absolute orbit 10102)

With associated S04 (nominal diffuser sequence) in order to compute ageing:

S04 sequence (diffuser 1) on 25/01/2018 04:11 to 04:13 (absolute orbit 10101)

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.

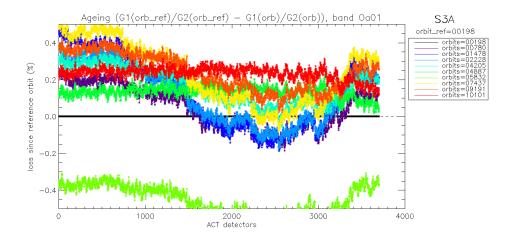


Figure 20: diffuser 1 ageing for spectral band Oa01. We see strong ACT low frequency structures that are due to residual of BRDF modelling.

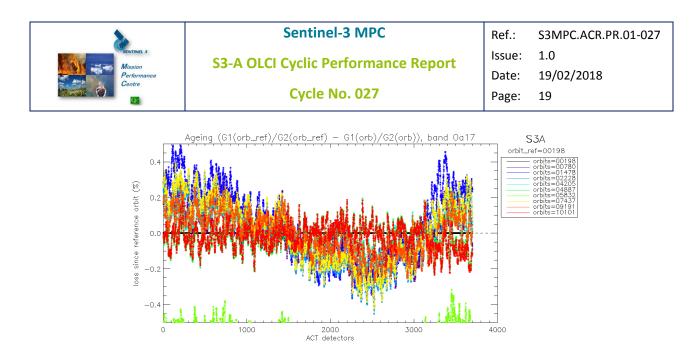


Figure 21: same as Figure 20 for spectral band Oa17. We use this band in order to normalize other bands and remove the ACT structures due to residual of BRDF modelling. Normalized curve for spectral band Oa01 is presented in Figure 22.

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.

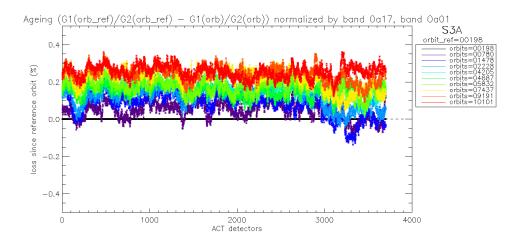


Figure 22: same as Figure 20 after normalization by band Oa17. Ageing of the diffuser 1 is now visible in the 5 cameras.

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.



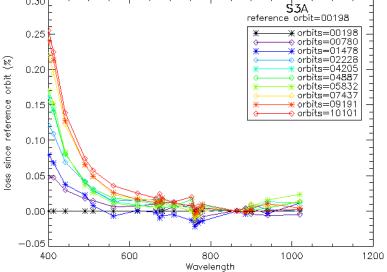


Figure 23: Diffuser 1 ageing as a function of wavelength (or spectral band). Ageing is clearly visible in spectral band #1 to #5.

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

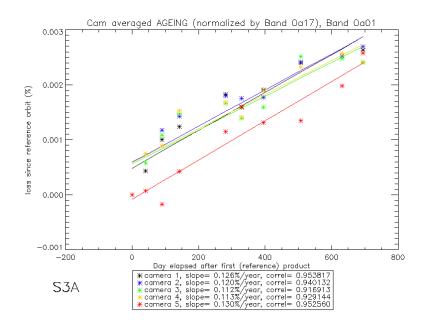


Figure 24: Camera averaged ageing (normalized by band Oa17) as a function of elapsed time. Linear fit for each camera is plotted. The slope (% loss per year) and the correlation coefficient

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).

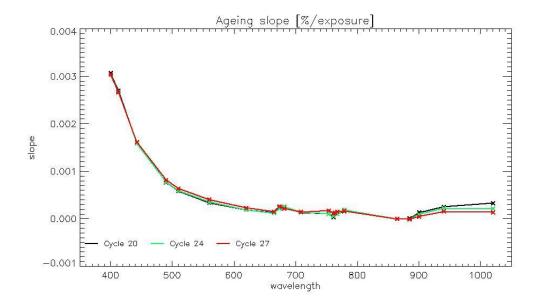


Figure 25: Slope of ageing fit (% of loss per exposure) vs wavelengths, using all the available ageing sequence at the time of the current cycle (red curve), at the time of cycle #24 (green curve) and at the time of cycle #20 (black curve)

In Figure 25, we see that the Ageing slopes have not significantly changed between the current Cycle and the last two cycles with a S05 sequence (cycles #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 one Calibration ADF generation during the current cycle.

S3A_OL_1_CAL_AX_20180125T041112_20991231T235959_20180208T120000______MPC_O_AL_018.SEN3

It contains updated Dark Tables (from RC of 25/01/2018) and new Geometric Calibration Models correcting the pointing drifts (see section 2.5). It has been provided to MPC-CC on 08/02/2018 for implementation in the PDGS at first opportunity.

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 027 and results presented in previous report are still valid.



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

There has been no Spectral Calibration acquisitions sequence during cycle 027.

Consequently, last results, presented in cycle 025 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 26.

SNR computed for all calibration data as a function of orbit number for band Oa01 (the less stable band) is presented in Figure 27.

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

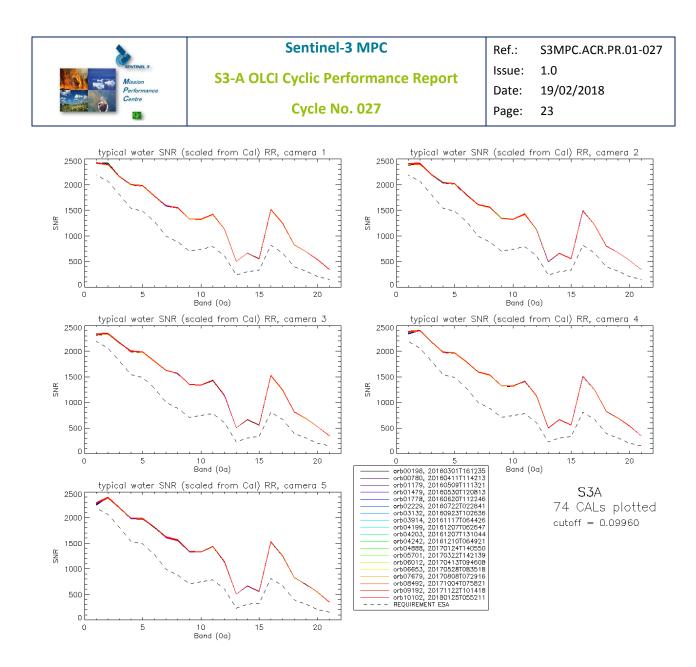


Figure 26: Signal to Noise ratio as a function of the spectral band for the 5 cameras. These results have been computed from radiometric calibration data. All calibrations except first one (orbit 183) are presents with the colours corresponding to the orbit number (see legend). The SNR is very stable with time: the curves for all orbits are almost superimposed. The dashed curve is the ESA requirement.



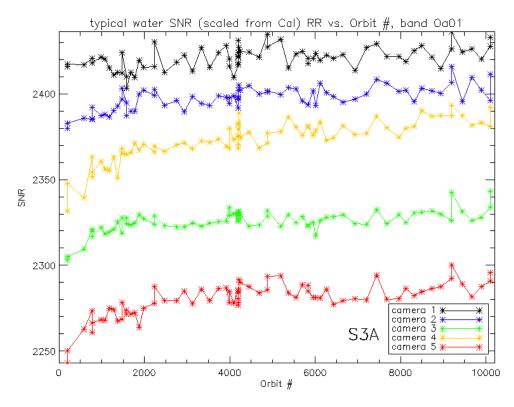


Figure 27: long-term stability of the SNR estimates from Calibration data, example of channel Oa1.

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.



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	C2		C3		C4		C5		All	
nm	LU	RQT	avg	std	avg	std	avg	std	avg	std	avg	std	avg	std
400.000	63.0	2188	2420	6.3	2397	6.8	2325	6.3	2372	11.7	2280	9.8	2359	7.1
412.000	74.1	2061	2395	7.4	2409	5.4	2340	4.9	2402	4.5	2386	7.0	2386	3.9
442.000	65.6	1811	2161	5.2	2200	5.6	2166	4.7	2186	4.1	2197	4.7	2182	3.3
490.000	51.2	1541	2000	5.1	2036	5.5	1996	3.8	1981	4.0	1988	5.0	2000	3.6
510.000	44.4	1488	1979	5.4	2013	5.1	1983	4.8	1966	4.8	1984	4.8	1985	4.0
560.000	31.5	1280	1776	4.4	1802	4.4	1801	4.7	1794	4.2	1818	3.6	1798	3.2
620.000	21.1	997	1591	4.2	1610	4.3	1625	3.2	1593	3.4	1615	3.9	1607	2.8
665.000	16.4	883	1546	4.7	1559	4.2	1567	4.0	1533	4.0	1560	4.0	1553	3.3
674.000	15.7	707	1329	3.3	1338	3.8	1350	2.9	1324	3.0	1342	4.0	1336	2.6
681.000	15.1	745	1320	3.7	1327	3.1	1337	2.9	1314	2.6	1333	3.9	1326	2.3
709.000	12.7	785	1420	4.7	1421	4.5	1434	3.6	1414	3.7	1429	3.2	1424	3.2
754.000	10.3	605	1127	3.4	1120	3.1	1134	3.7	1124	2.6	1138	3.1	1128	2.7
761.000	6.1	232	502	1.3	498	1.3	505	1.3	500	1.1	507	1.5	502	1.0
764.000	7.1	305	662	1.7	657	1.6	667	2.3	661	1.7	669	2.1	663	1.5
768.000	7.6	330	558	1.8	554	1.3	562	1.3	556	1.6	564	1.4	559	1.2
779.000	9.2	812	1514	5.1	1497	5.1	1523	5.6	1510	5.5	1525	5.2	1514	4.7
865.000	6.2	666	1244	3.8	1213	4.3	1238	4.2	1246	3.9	1250	3.1	1238	3.4
885.000	6.0	395	823	1.8	801	1.7	814	2.1	824	1.6	831	1.8	818	1.3
900.000	4.7	308	691	1.5	673	1.3	683	1.8	693	1.5	698	1.5	687	1.1
940.000	2.4	203	534	1.1	522	1.1	525	1.0	539	1.2	542	1.3	532	0.8
1020.000	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

Regular monitoring using the GeoCal Tool implemented within the MPMF continues. Latest results confirm good performance. Monitoring of the geolocation performance by correlation with GCP imagettes using the GeoCal tool over the period confirms that OLCI is *globally* compliant with its requirement: the centroid of the geolocation error is around 0.3 and 0.4 pixel in across-track and along-track directions respectively (Figure 28 & Figure 29). Completion of the time series (started using the

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partial reprocessing dedicated to validation: 4 days every month between 26/04/16 and 12/03/2017) confirms the slow AL performance degradation (Figure 30).

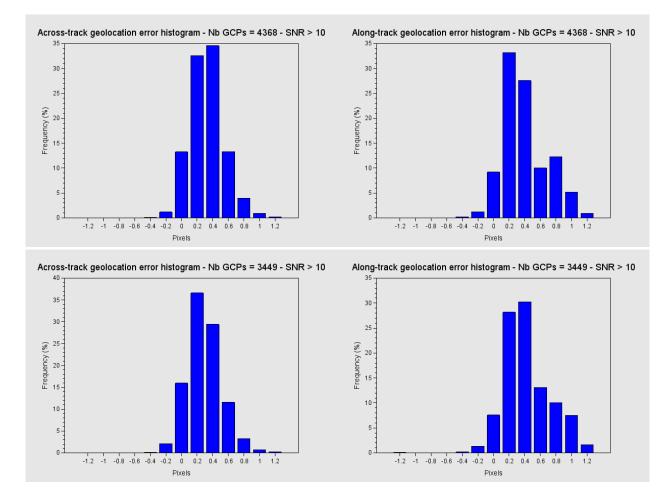


Figure 28: histograms of geolocation errors for the along-track (left) and across-track (right) directions, examples of 17/01/2018 (top) and 11/02/2018 (bottom).



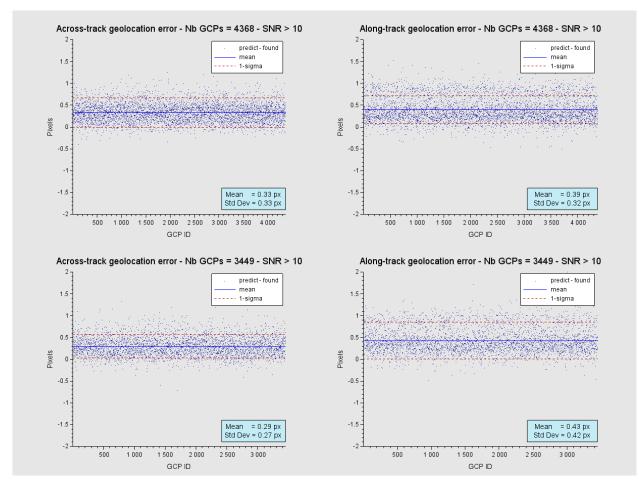


Figure 29: georeferencing error in along-track (left) and across-track (right) directions for all the GCPs, examples of 17/01/2018 (top) and 11/02/2018 (bottom).



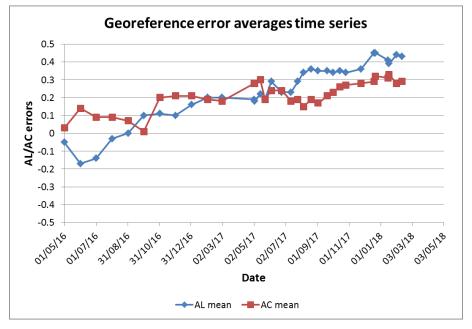


Figure 30: time series of geolocation errors for the along-track (blue) and across-track (red) directions over 21 months.

Per camera analysis has pointed out a significant drift of camera 3, yielding to non-compliance of that camera, as shown on Figure 31 below.

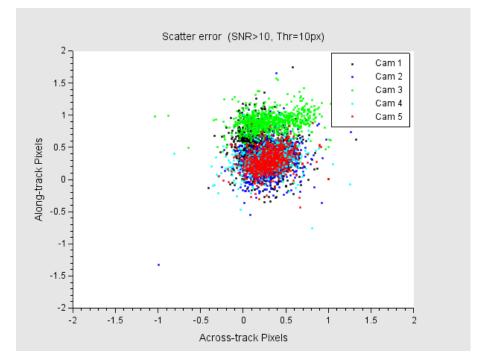


Figure 31: residual geolocation errors for the 31/01/2018: camera 3 (green circles) is clearly out of the general trend with a significant along-track bias.

An updated set of Geometric Calibration Models trained on data from the second half of 2017 has been delivered by ESTEC mid-December and has been validated by the S3-MPC. Results of this validation are

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shown on Figure 32 (left) as residuals of GCPs geolocation errors. Figure 32 (right) shows the same for the equivalent data set processed with the current Processing Baseline. The improvement is clear and further highlighted by the statistics given in Table 2 (reprocessed data) and Table 3 (current baseline). Geolocation performance time series on an extended data set, up to end January 2018, is shown on Figure 33 for all cameras, highlighting the very good stability. These updated GCMs, now considered validated for their use over 2018, should be put in production as soon as possible.

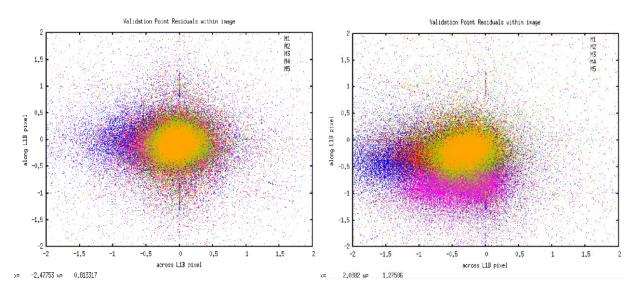


Figure 32: validation of the updated Geometric Calibration Models: residual geolocation error using new models (left) compared to those using current baseline on same data set. The validation data set extends from 15/10 to 29/11/2017, i.e. outside the ESTEC training set.

Camera	biasAcross	biasAlong	sigmaAcross	sigmaAlong
1	-0.135143	-0.043965	0.004293	0.005967
2	-0.060582	-0.050120	0.005072	0.006990
3	-0.047512	-0.062590	0.005707	0.007773
4	-0.024701	-0.059935	0.005941	0.008315
5	-0.034563	-0.065549	0.005800	0.008051
RMS	0.072105	0.057011	0.005397	0.007468
	Ab	s. RMS bias = 0.0	91921	

 Table 2: validation of the updated Geometric Calibration Models: residual geolocation error statistics using

 reprocessed data.



Table 3: validation of the updated Geometric Calibration Models: residual geolocation error statistics using current baseline data.

current busenne uutu.					
Camera	biasAcross	biasAlong	sigmaAcross	sigmaAlong	
1	-0.508307	-0.382777	0.004245	0.005781	
2	-0.417185	-0.274206	0.005023	0.006684	
3	-0.357014	-0.767102	0.005626	0.007451	
4	-0.315060	-0.232083	0.005872	0.007952	
5	-0.294829	-0.196981	0.005738	0.007775	
RMS	0.386281	0.424927	0.005335	0.007174	
Abs. RMS bias = 0.574261					

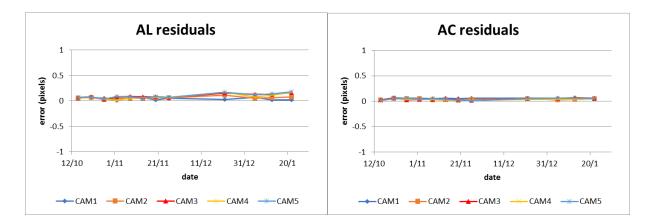


Figure 33: time series f along-track (left) and across-track (right) geolocation performance on the reprocessed data set, completed by 5 additional dates: 22/12/2017, 05/01/2018, 13/01/2018 and 22/01/2018..



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3 OLCI Level 1 Product validation

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

3.1.1 S3ETRAC Service

Activities done

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

All details about the S3ETRAC/OLCI and S3ETRAC/SLSTR statistics are provided on the S3ETRAC website <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.

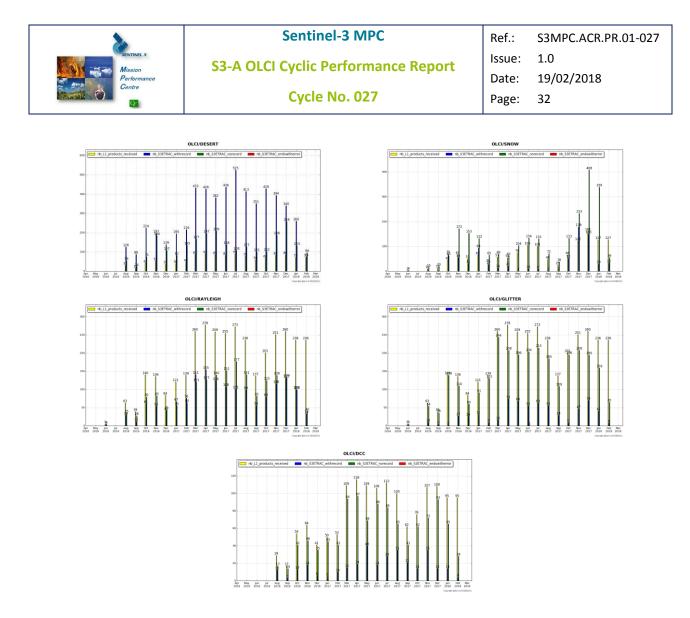


Figure 34: summary of S3ETRAC products generation for OLCI (number of OLCI L1 products Ingested, yellow – number of S3ETRAC extracted products generated, blue – number of S3ETRAC runs without generation of output product (data not meeting selection requirements), green – number of runs ending in error, red, one plot per site type).

3.1.2 Radiometric validation with DIMITRI

Highlights

- Run Rayleigh and Desert methods over the available products until 12th February 2018.
- About 90 new products from Cycle-27 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.
- The time-series over PICS, Rayleigh and Glint methods from the reprocessed products (REP006: July 2016-July 2017; December 2017 for PICS) over 12 CalVal sites are analysed, and seem to be consistent with the results of the current processing baseline (PB:2.23)..



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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 12th February 2018.
- 2. The results are consistent overall the six used PICS sites (Figure 35). OLCI reflectance shows a good stability over the analysed period.
- 3. The temporal average over the period April 2016 12th February 2018 of the elementary ratios (observed reflectance to the simulated one) shows values higher than 2% (mission requirements) over all the VNIR bands (Figure 36). The spectral bands with significant absorption from water vapour and O₂ (Oa11, Oa13 and Oa14) 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 images too. It is most likely related to human/industrial activity in the area.



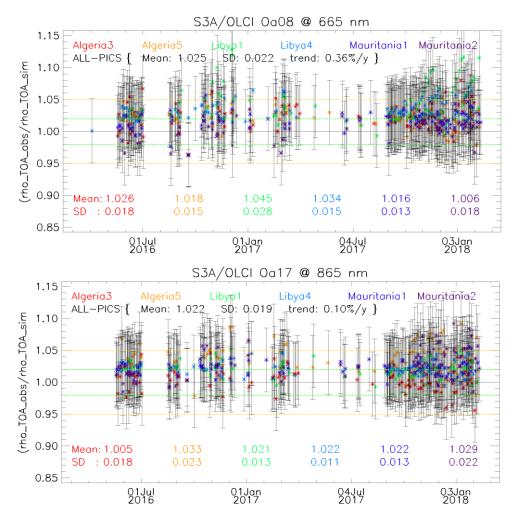


Figure 35: Time-series of the elementary ratios (observed/simulated) signal from S3A/OLCI for (top to bottom) bands Oa03, Oa8 and Oa17 respectively over Six PICS Cal/Val sites. Dashed-green and orange lines indicate the 2% and 5% respectively. Error bars indicate the desert methodology uncertainty.



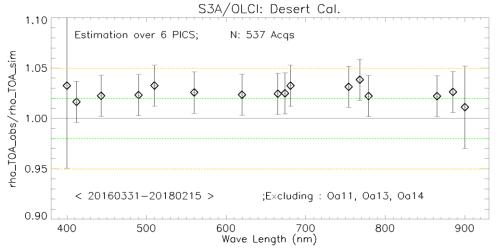


Figure 36: The estimated gain values for S3A/OLCI over the 6 PICS sites identified by CEOS over the period April 2016 – February 2018 as a function of wavelength. Dashed-green and orange lines indicate the 2% and 5% respectively. Error bars indicate the desert methodology uncertainty.

II-Intercomparison S3A/OLCI, S2A/MSI, LANDSAT/OLI and Aqua/MODIS over PICS

X-mission Intercomparison with MODIS-A and MSI-A has performed until December 2017 and February 2018 respectively. Figure 37 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 February 2018 (for OLCI and MSI).

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

Figure 38 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 with S2A/MSI. The spectral bands with significant absorption from water vapour and O_2 are excluded. OLCI-A seems to have higher gain (Figure 38) than the other sensors, which means that OLCI-A has higher reflectance that the ones simulated by the PICS method.



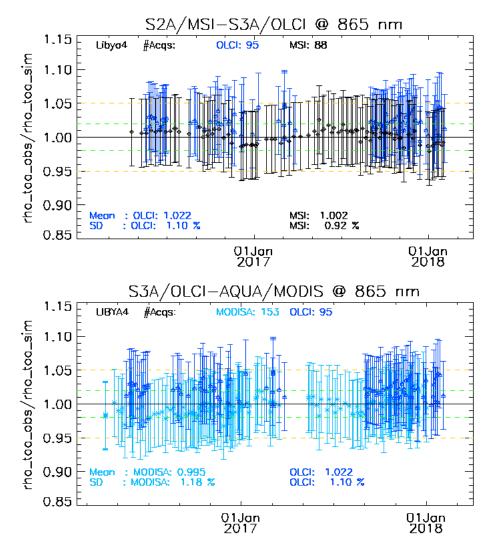


Figure 37: Time-series of the elementary ratios (observed/simulated) signal from (black) S2A/MSI, (blue) S3A/OLCI, and (Cyan) MODIS-A for band Oa17 (865nm) over the LIBYA4 site. Dashed-green and orange lines indicate the 2% and 5% respectively. Error bars indicate the desert methodology uncertainty.

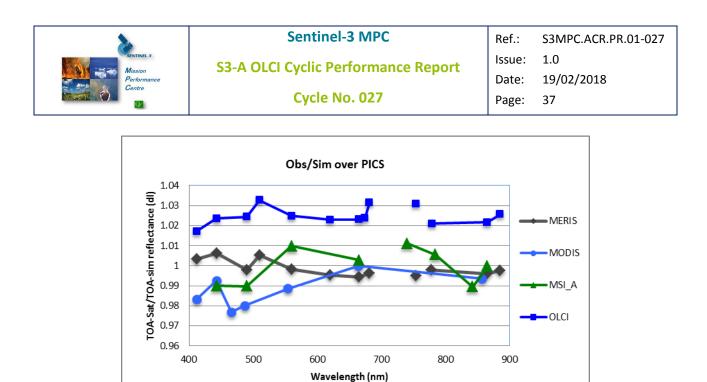


Figure 38: Ratio of observed TOA reflectance to simulated one for (black) MERIS/3REP, (green) S2A/MSI, (cyan) Aqua/MODIS and (blue) S3A/OLCI averaged over the six PICS test sites as a function of wavelength.

III-Validation over Rayleigh

Rayleigh method has been performed over the available mini-files on the Opt-server until February 2018. The results produced with the configuration (ROI-AVERAGE) are consistent with the results of PICS method and from Cycles 26. While bands Oa01-Oa05 display a bias values between 2%-5%, bands Oa6-Oa9 exhibit biases within 2% (mission requirements) (Figure 39 and Figure 40).

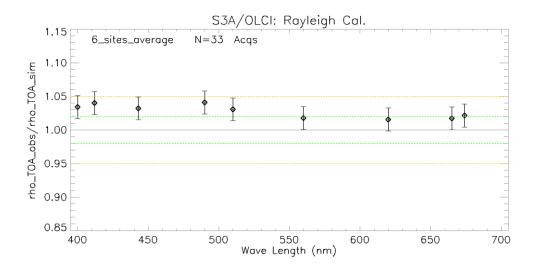


Figure 39: The estimated gain values for S3A/OLCI over the 6 Ocean CalVal sites (Atl-NW_Optimum, Atl-SW_Optimum, Pac-NE_Optimum, Pac-NW_Optimum, SPG_Optimum and SIO_Optimum) over the period November 2016 – February 2018 as a function of wavelength. Dashed-green, and orange lines indicate the 2%, 5% respectively. Error bars indicate the methodology uncertainty.

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IV-Validation over Glint

Glint calibration method with the configuration (ROI-PIXEL) has been performed over the period December 2016 – February 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 (see Figure 40).

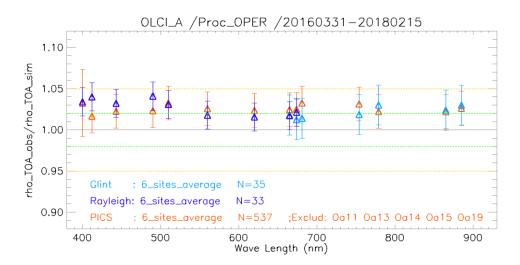


Figure 40: The estimated gain values for S3A/OLCI from Glint, Rayleigh and PICS over the period April 2016 – February 2018 for PICS and December 2016- February 2018 for Glint and Rayleigh methods as a function of wavelength. We use the gain value of Oa8 from PICS method as reference gain for Glint. Dashed-green and orange lines indicate the 2% and 5% respectively. Error bars indicate the methods uncertainties.

V-Validation of the reprocessed products over ocean and desert sites from REP006

The time-series over PICS have been completed over the available granules from the reprocessed products (REP006: July 2016 – July 2017; until Dec. 2017 for PICS) over the 6 PICS CalVal sites. PICS method results show a slightly lower gain coefficients wrt the results of the current processing baseline (PB:2.23)), but similar sensor stability (Figure 41). This could be related to the different averaging periods however the differences are still within the methods error (~1%).

The outcome of this analysis shows a good consistency with the results of the current processing baseline (PB:2.23) over the VNIR spectral range (see Figure 41).



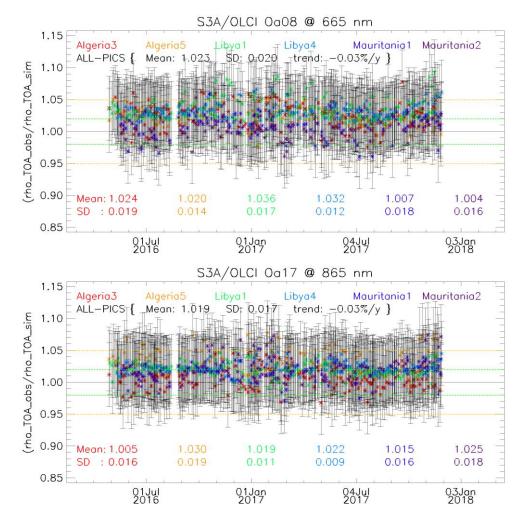
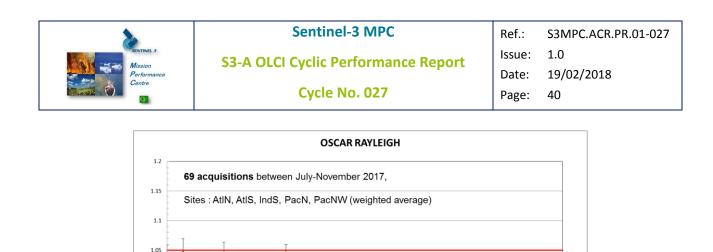


Figure 41: Time-series of the elementary ratios (observed/simulated) signal from S3A/OLCI products (REP006: July 2016 – December 2017) for (top to bottom) bands Oa08 and Oa17 respectively over Six PICS Cal/Val sites. Dashed-green and orange lines indicate the 2% and 5% respectively. Error bars indicate the desert methodology uncertainty.

3.1.3 Radiometric validation with OSCAR

The average OSCAR Rayleigh results and the standard deviation calibration are shown below (Figure 42). Please note that the OSCAR Rayleigh results for band Oa01 have to be considered with care due to larger uncertainty in the radiative transfer calculation. Observed biases for Oa01-Oa05 are between 2.5% - 4.5%, for Bands Oa6-Oa9 observed biases are lower, well within the 2 % mission requirement.



Ŧ Ŧ Ŧ

700

650

Measured/simulated

0.9

0.85

0.8

450

500

Figure 42: OSCAR Rayleigh Calibration results: weighted average over all sites and standard deviation for July 2017 till November 2017.

550

Wavelength (nm)

600

In Figure 43, the average OSCAR Glitter results are given, excluding the bands in the Blue spectral region and the atmospheric absorption bands. The results in Figure 43 are "relative" interband calibration results. This means that results are given relative to the reference band, which is the Red band at 655 nm. In Figure 3 the Glitter results are given "absolutely" by adapting the results to the Rayleigh calibration results at 665 nm.

Overall OLCI shows an excess of radiance. For the Blue bands (Oa1-Oa5) and 1020 nm band (Oa21 nm) the bias is in the order of 2.5 to 4.5 %. For the others bands the excess of radiance about 1 to 2%. Excluding the bands in the Blue spectral region and the atmospheric absorption bands, the interband consistency is well within the requirements of 2%.



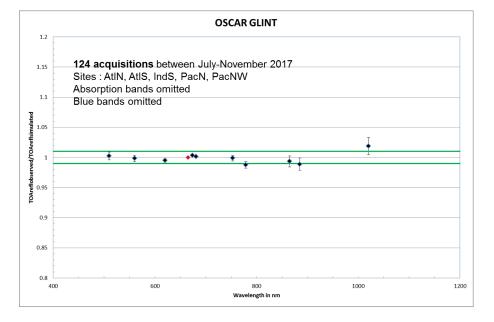


Figure 43: OSCAR Glitter results: weighted average over all sites and standard deviation for July 2017 till November 2017 .

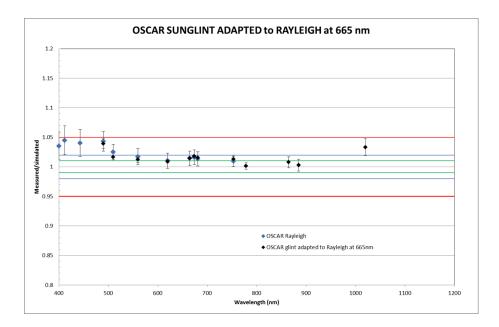


Figure 44: OSCAR Glitter results adapted to the Rayleigh calibration result at665 nm (black) on top of OSCAR Rayleigh results (blue).

3.1.4 Inter-comparison of DIMITRI and OSCAR Rayleigh results

The two implementations of the Rayleigh method used at S3-MPC give extremely consistent results (within 0.7%, well below the claimed accuracy, Figure 45). However this does not imply that they are more reliable than the other methods: the Rayleigh method is for instance suspected to overestimate

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the simulated signal in the blue region whatever the sensor and the implementation. The fact that standard deviations are higher for DIMITRI is likely to be due to the difference in the datasets: 29 samples for DIMITRI against 69 for OSCAR.

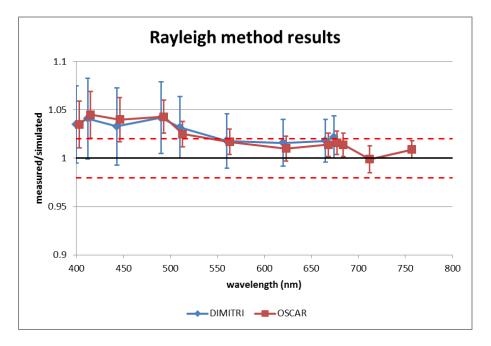


Figure 45: DIMITRI (blue) and OSCAR (red) Rayleigh Calibration results: weighted average over all sites and standard deviations.

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

4.1.1.1 Summary

OGVI has been compared, for a number of sites, with In-situ data, with FAPAR derived from MODIS 250m imagery, and with MERIS climatology data (toa_veg from 3rd reprocessing). The sites include 3 in Germany, 4 in Italy, 3 in the USA, 2 in Russia, 2 in Spain and 1 in the UK. In-situ data is available over a limited timespan for 1 Spanish and the UK and US sites.

The comparison with MERIS is the most interesting given that OLCI is the successor to MERIS. However, no direct comparison is possible given that there is no overlap between their operating time periods. Nevertheless the comparison shows that the current OGVI data conform well to the MERIS climatological trends (Figure 48).

The correlation figures with MODIS are very significant. The algorithm used to calculate the OLCI and MODIS FAPAR is the same, and whilst we can expect some error due to different instruments and the necessary re-projection, the high correlation over a large number of points in different vegetative scenarios is an indication of the reliability of the OGVI product (Figure 49 & Table 4).

No final conclusions can be associated with in-situ comparisons, but this is due to solely quantitative and qualitative aspects of the In-situ data. At both sites, the OGVI appears to be subject to some degree of underestimation, particularly at the peak of the growing season (Figure 46). However, rather than being caused by deficiencies in the product, some degree of underestimation is expected due to differences in the definition of the in-situ estimates, which measure the amount of PAR absorbed by the entire canopy, as opposed to that absorbed by only its green elements.

Notes: The recently distributed reprocessed data is referred to as rp218a.

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Mission Performance	55 A Oler Cyclic I chomance Report	Date:	19/02/2018
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4.1.1.2 In situ comparisons

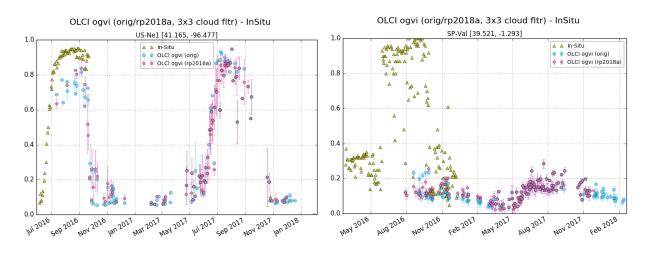
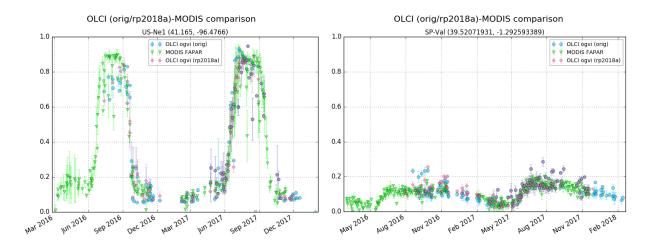


Figure 46: Time-series of the OGVI and In-Situ derived FAPAR over the US-Ne1 (L) and SP-Val (R) sites.

The OGVI presented here includes the original data and the reprocessed data. A 3x3 cloud filter has been applied over the relevant points.

At both sites, the OGVI appears to be subject to some degree of underestimation, particularly at the peak of the growing season (Figure 46). However, rather than being caused by deficiencies in the product, some degree of underestimation is expected due to differences in the definition of the in-situ estimates, which measure the amount of PAR absorbed by the entire canopy, as opposed to that absorbed by only its green elements.



4.1.1.3 Modis comparisons

Figure 47: Time-series of the OGVI and MODIS derived FAPAR over the US-Ne1 (L) and SP-Val (R) sites.



The comparison is made by reprojecting the OLCI OGVI data on the MODIS platecarrée 250m projection using the GPT tool and comparing the identical pixel locations.

4.1.1.4 MERIS Climatology comparisons

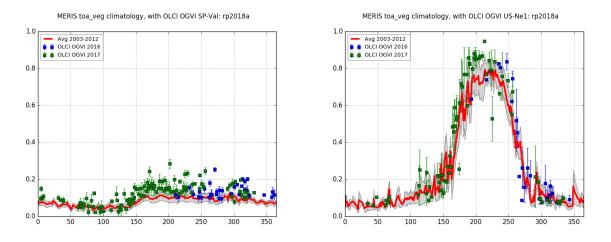


Figure 48: Time-series of the OGVI and MERIS toa_veg climatology over the US-Ne1 (L) and SP-Val (R) sites.

4.1.1.5 Scatter plots for OGVI and MODIS derived FAPAR

These data are for all the point under consideration for dates where ogvi and MODIS data are available. Ttwo scatter plots are presented, one for the original data and the second for the rp2018a reprocessed data. The scatter plots are then reproduced limiting the data to the two points, US-Ne1 and SP-Val for the rp2018a reprocessed data only.

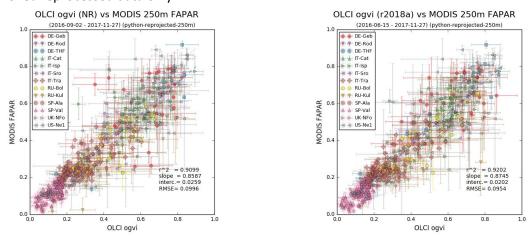


Figure 49: Scatter plots for ogvi – MODIS derived FAPAR for the original data (L) and rp2018a (R).



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Table 4: Correlation statistics for original and rp2018a OGVI/MODIS FAPAR comparison

	Original	Rp2018a
r²	0.91	0.92
RMSE	0.0996	0.0954

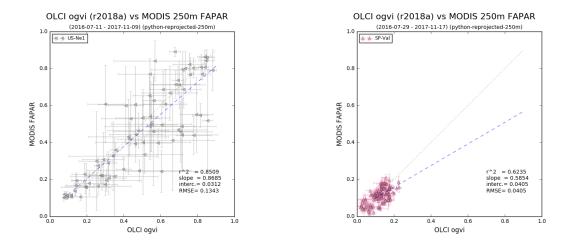


Figure 50: Scatter plots for OGVI (rp2018a) – MODIS derived FAPAR for the US-Ne1 (L) and SP-Val (R) sites.

4.1.2 OLCI Terrestrial Chlorophyll Index (OTCI)

Indirect verification of the OTCI has been conducted over core validation sites, and good temporal consistency has been demonstrated, with expected seasonal patterns clearly revolved over these sites. In addition, the OTCI has demonstrated very good consistency with a monthly climatology established over these sites from Medium Resolution Imaging Spectrometer (MERIS) data, providing confidence in its ability to deliver continuity to the 10-year MERIS archive (Figure 51).

Direct validation efforts have involved the collection of in-situ estimates of canopy chlorophyll content (CCC), which have been upscaled to OLCI spatial resolution using high spatial resolution imagery. The first direct validation effort took place over a 1 km x 1 km area of the New Forest, a deciduous broadleaf forest site in the United Kingdom. Field campaigns took place between April and November 2016, with a multi-temporal approach adopted to capture the required range in canopy chlorophyll content (CCC). 9 elementary sampling units (ESUs) were sampled 8 times during the growing season, and Sentinel-2 Multispectral Instrument (MSI) data were used for upscaling. A very strong relationship between the OTCI and CCC was demonstrated (Figure 52).

The second direct validation effort took place over a 10 km x 10 km area of the Valencia Anchor Station, a Mediterranean site in Spain. This field campaign took place in July 2017. 49 ESUs were sampled, and airborne hyperspectral data was collected to facilitate upscaling. Initial results reveal indicate that good spatial consistency is demonstrated between the OTCI and CCC, which was upscaled using a Sentinel-2

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MSI scene due to ongoing processing of the airborne hyperspectral data (Figure 53). Reliable quantitative comparison has so far been limited by co-registration issues, and methods to resolve these issues are currently being explored. Use of the airborne hyperspectral data for upscaling is expected to provide refined validation results in the near future.



Sentinel-3 MPC

S3-A OLCI Cyclic Performance Report

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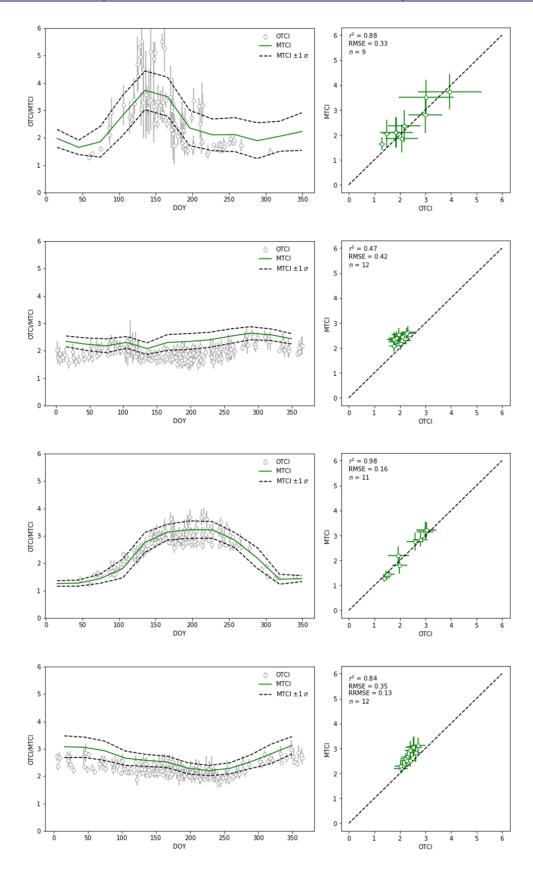


Figure 51: Time-series (left) and scatter plots (right) of the OTCI with respect to the monthly mean MTCI over the DE-Geb (top), IT-Cat (middle-top), IT-Isp (middle-bottom) and IT-Sro (bottom) sites.



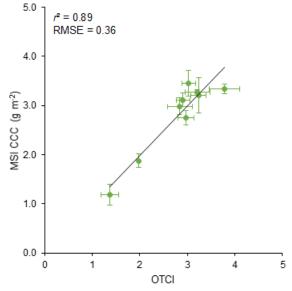


Figure 52: Relationship between OTCI and CCC upscaled to OLCI spatial resolution using Sentinel-2 MSI data over the New Forest.

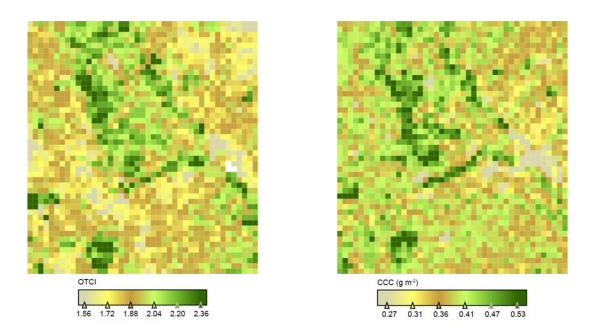


Figure 53: Spatial consistency between the OTCI (left) and CCC upscaled to OLCI spatial resolution using Sentinel-2 MSI data (right) over the Valencia Anchor Station.



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

Providing clear sky conditions for production of Sentinel-3 OLCI Level 2 products is essential to ensure a good and reliable Level 2 product quality for the users. The OLCI Level 2 cloud flag available during commissioning phase did not fulfill these requirements. Therefore, a big effort was taken by the Sentinel-3 MPC to improve the level 2 cloud flagging algorithms. The new cloud flagging is implemented in the current operational and reprocessed products.

The current cloud flagging algorithm consists of a combination of spectral tests and a neural net (NN). With the introduction of the NN to the current algorithm two additional flags have been introduced. A flag called CLOUD_AMBIGUOS identifying pixels which are not identified as clouds by the spectral tests and not as clouds with a high level of confidence by the NN. In contrast to the pixels flagged as CLOUD, the level 2 processors are producing data below the CLOUD_AMBIGUOUS flagged pixels. Additionally, for FR product, a 4 pixels wide (respectively 2 pixels for RR products) cloud margin is computed around the CLOUD_AMBIGUOUS flags. The L2 processor is also producing data below the CLOUD_MARGIN pixels. These two additional flags give the user the possibility to either use a less or a more restrict cloud flagging. The set of available cloud flags in the L2 product is shown in Figure 54.

LQSF_INVALID	Maths	0.5 LQSF.INVALID
LQSF_WATER	Maths	0.5 LQSF.WATER
LQSF_LAND	Maths	0.5 LQSF.LAND
	Maths	0.5 LQSF.CLOUD
LQSF_CLOUD_AMBIGUOUS	Maths	0.5 LQSF.CLOUD_AMBIGUOUS
LQSF_CLOUD_MARGIN	Maths	0.5 LQSF.CLOUD_MARGIN
LQSF_SNOW_ICE	Maths	0.5 LQSF.SNOW_ICE

Figure 54: The current set of cloud flags

To quantitatively evaluate the current cloud flag, a dedicated validation was conducted using 10,000 manually collected (classified) pixels. The collection was done using a dedicated software tool called PixBox. The collected pixels are well distributed temporally and spatially (see Figure 55).



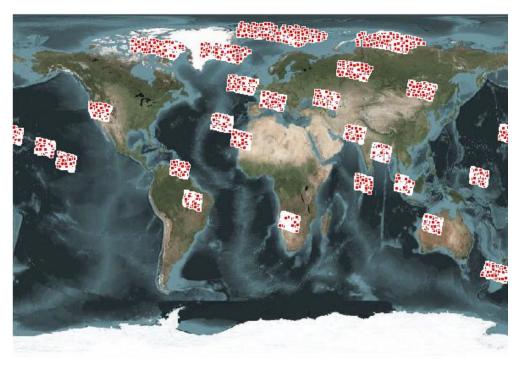


Figure 55: spatial distribution of the PixBox validation dataset samples

The collection distinguishes between different cloud types which have been combined to one cloud category for the validation. The same has been done for the OLCI L2 cloud flags (CLOUD, CLOUD_AMBIGUOUS, CLOUD_MARGIN), as there is no straight forward correlation between the collected cloud types and the three OLCI L2 cloud flags.

The validation has been split into three parts, a validation over all surfaces, a validation over water surfaces and a validation over land surfaces. This split was done to see how the flagging performs overall and for the two different products (land & ocean). The validation has shown the following results.

The validation of the cloud flag over all surfaces (land & water) has shown (see Figure 56) an overall accuracy (OAA) of over 86% and a user accuracy (UA) for clear pixels of over 92%. The level of significance (0.72) is substantial. From the user perspective the cloud flags have a good accuracy in identifying clear observations, but from the producer perspective there is room for improvements, as the producer accuracy (PA) of clear pixels is only a little above 81%. This means, there is a commission error of clear pixels of above 19% and an omission error of cloud pixels of 8.1%.



OLCI LFR cloud val. - all surface (Insitu 1-5 vs CLD Flags) In-Situ Database

	Class	Clear	Cloud	Sum	U A	E
	CLEAR	3856	330	4186	92.1	7.9
I FR	CLOUD	900	3756	4656	80.7	19.3
OLCI FR	Sum	4756	4086	8842		
	ΡA	81.1	91.9		OAA:	86.09
	E	18.9	8.1			

Scotts Pi: 0.721 Krippendorfs alpha: 0.721 Cohens kappa: 0.722

Figure 56: Validation dataset Confusion Matrix for all surfaces

When analysing only water surfaces (see Figure 57) the accuracies are distributed a bit different compared to looking at all surfaces. The OOA is a bit higher (87%) while the UA for clear pixels is a lot lower, with only 86.7%. The omission error of cloud pixels over water is nearly 3% higher (10.9%) compared to all surfaces (8.1%). On the other hand, the comission error of clear pixels decreased over water surfaces nearly 7%.

	Class	Clear	Cloud	Sum	U A	E
	CLEAR	1710	263	1973	86.7	13.3
I FR	CLOUD	305	2153	2458	87.6	12.4
OLCI FR	Sum	2015	2416	4431		
	ΡA	84.9	89.1		OAA:	87.18
	E	15.1	10.9			

OLCI WFR cloud val. - water surface (Insitu 1-5 vs CLD Flags) In-Situ Database

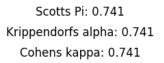


Figure 57: Validation dataset Confusion Matrix for water surfaces

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When analysing only land surfaces (see Figure 58) the accuracies again are distributed a bit different compared to all surfaces. The OOA is a bit lower (85%) while the UA for clear pixels is a lot higher, with only 97%. The omission error of cloud pixels over land is 4% lower (4%) compared to all surfaces (8.1%). On the other hand, the comission error of clear pixels increases over land surfaces nearly 8%. With 27% the comission error over land is relatively high, but as previous analysis have shown the comission error occures predominantly over bare surfaces which do not have values for OTCI or OGVI. However, here is some room for improvement.

	Class	Clear	Cloud	Sum	U A	E	
OLCI FR	CLEAR	2178	67	2245	97.0	3.0	
	CLOUD	596	1603	2199	72.9	27.1	
	Sum	2774	1670	4444			
	ΡA	78.5	96.0		OAA:	85.08	
	E	21.5	4.0				

OLCI LFR cloud val. - land surface (Insitu 1-5 vs CLD Flags) In-Situ Database

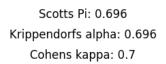


Figure 58: Validation dataset Confusion Matrix for land surfaces

As a summary it can be said that the current OLCI L2 cloud flag is robust but clearly cloud conservative.



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 027. 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.

The results presented in this section present the level-2 FR quantitative validation performed over the full OLCI time series against situ fiducial reference measurements. OLCI data used in these sections correspond to the last processing baseline (IPF version 6.11, PB 2.23). In situ data collected originate from the following stations or buoys:

- AERONET-OC <u>https://aeronet.gsfc.nasa.gov/new_web/ocean_color.html</u>
- BOUSSOLE <u>http://www.obs-vlfr.fr/Boussole/html/project/strategy.php</u>
- MOBY <u>https://www.star.nesdis.noaa.gov/sod/moby/gold/</u>
- SLGO <u>https://slgo.ca/en/</u>

5.2.1 Global scale validation

5.2.1.1 Level-2 products filtering procedure

The flags used in the computations of the statistics over OLCI macropixels correspond to S3VT recommended flags and are listed below:

INVALID, CLOUD, CLOUD_AMBIGUOUS, CLOUD_MARGIN, SNOW_ICE, SUSPECT, HISOLZEN, SATURATED, RISKGLINT, WHITECAPS, AC_FAIL, OC4ME_FAIL, ANNOT_TAU06, ANNOT_ABSO_D, ANNOT_DROUT, RWNEG_O2 to RWNEG_O8, ANNOT_MIXR1.

Additional filtering includes time difference between in situ measurement and satellite over path below 6 hours, wind speed lower than 9m.s⁻¹ and sun zenith angle lower than 60 degrees. Filtered mean and CV tests as described in Bailey and Werdell (2006) is also included in the filtering process.

Ref: W. Bailey and P.J. Werdell, "A multi-sensor approach for the on-orbit validation of ocean color satellite data products", Rem. Sens. Environ. 102, 12-23 (2006).



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5.2.1.2 Global Results

Figure 59 presented below represent the scatterplots and statistics of OLCI full resolution radiometric products against in situ data collected at AERONET-OC, BOUSSOLE, MOBY and SLGO. The statistics are summarized in Table 5.

The total number of matchups varies from 322 to 106 depending on the wavelength. 400nm validation is only represented by BOUSSOLE and MOBY data while 665nm is only represented by AERONET-OC and SGLO IML4 station. Regression statistics are very good up to 560nm with sloped between 0.830 and 0.920 and r2 mostly around 0.8. The 665nm band is clear the most critical one with poor slopes and r² (0.406 0.428 respectively). At this stage of the mission, there are still no clues for the poor performance of this band. OLCI products are within the requirements (5% accuracy in the blue/green bands) as demonstrated by the RPD values. The sole outlier is represented by the 412nm band with a 29.3% RPD. This contrasts with the 400nm band. These two bands are indeed the most sensitive to atmospheric correction and one would expect a comparable performance. However, the graphs and statistics presented below at 412 include data from fairly complex waters and therefore significantly influence the statistics. UCSSeaprism Helsinki light house, MVCO, Thornton and Gustav Dalen tower AERONET-OC data are indeed in optically very complex waters. If we reduce the statistics to case one waters (MOBY and BOUSSOLE), as it is the case at 400nm, the 412nm statistics almost fit within the requirements with an RPD of -5.77% (see Figure 60).



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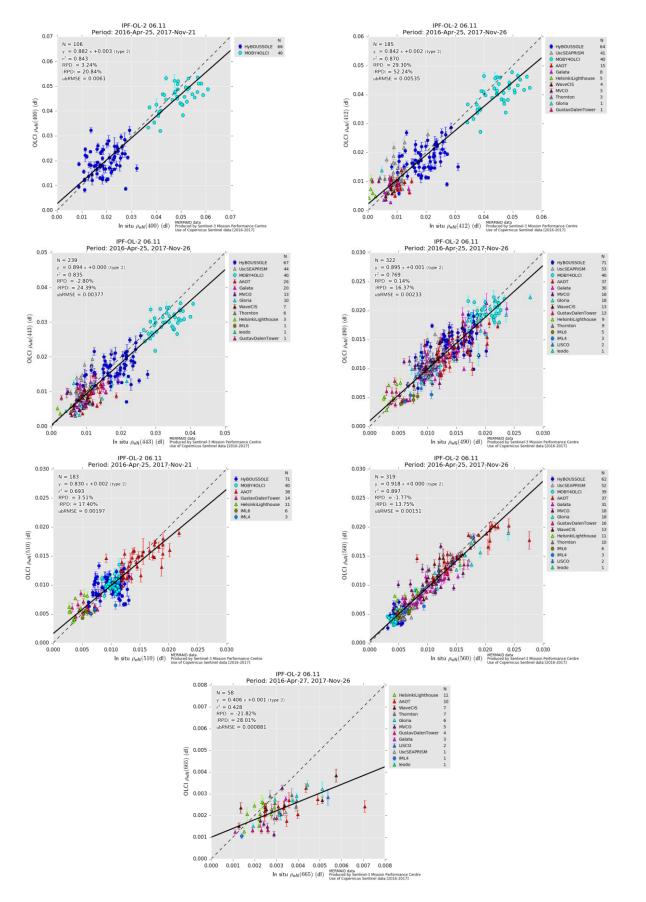


Figure 59: FR scatter plot of OLCI versus in situ measurements



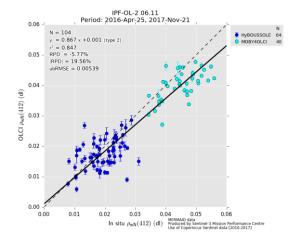


Figure 60: FR scatter plot of OLCI 412nm band versus in situ measurements collected at BOUSSOLE and MOBY

lambda	Ν	RPD	RPD	MAD	RMSE	ubRMSE	slope	intercept	r2
400	106	3.2%	20.8%	-0.0009	0.0062	0.0061	0.882	0.003	0.843
412	185	29.3%	52.2%	-0.0010	0.0054	0.0054	0.842	0.002	0.870
443	239	-2.8%	24.4%	-0.0013	0.0040	0.0038	0.894	0.000	0.835
490	322	0.1%	16.4%	-0.0004	0.0024	0.0023	0.895	0.001	0.769
510	183	3.5%	17.4%	-0.0001	0.0020	0.0020	0.830	0.002	0.693
560	319	-1.8%	13.8%	-0.0003	0.0015	0.0015	0.918	0.000	0.897
665	58	-21.8%	28.0%	-0.0008	0.0012	0.0009	0.406	0.001	0.428

Table 5: Summary of OLCI FR statistics.

OLCI vicarious was performed on both Fiducial Reference Measurements (FRM) and climatology. This was justified by the lack of sufficient in situ data to derive stable system vicarious gains. BOUSSOLE and MOBY data were used as FRM. GlobColour (GC) climatologies (<u>http://hermes.acri.fr</u>) were used in addition. GC climatologies were derived from merged SeaWiFS, MODIS and MERIS historical data. Statistically GC climatologies have the more weight in the final gains with about 90% of data used to derive SVC coming from climatologies.

Figure 61 below present the comparison between GC climatologies and OLCI level-3 products. As expected, OLCI and GC global level3 median time series are well in line although small differences are observed resulting in a maximum relative difference in July and August for both years at about 3% and 2% respectively. This seasonal variability is still not fully understood. The same patterns but in opposite phase are observed if OLCI is compared to MODIS or VIIRS.



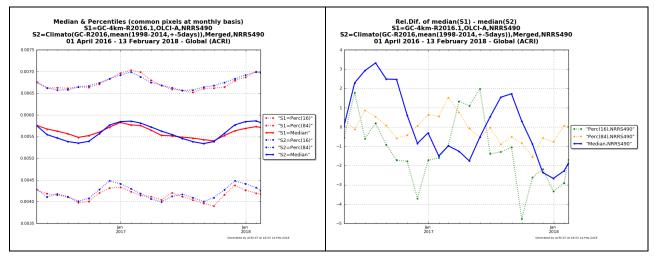


Figure 61: inter-comparison of OLCI and GlobColour climatology global level3 time series. Median and percentile (left), OLCI (blue) versus VIIRS (red). Relative difference (GC-OLCI)/OLCI (right)

Figure 62 and Figure 63 show global inter-comparison of MODIS, VIIRS and OLCI at level3 with mean and percentile as well as relative difference time series. A strong seasonal signal can also be observed while comparing VIIRS to OLCI and MODIS to OLCI resulting in a relative difference ranging from 0 up to 10%. The sensors are in a closer agreement in July, August and September. The seasonal signal can be observed at 412, 443, and 490 but not at 560nm. 510 is not assessed as neither MODIS nor VIIRS have a closed enough band for comparison. This seasonal signal is not observed between VIIRS and MODIS.

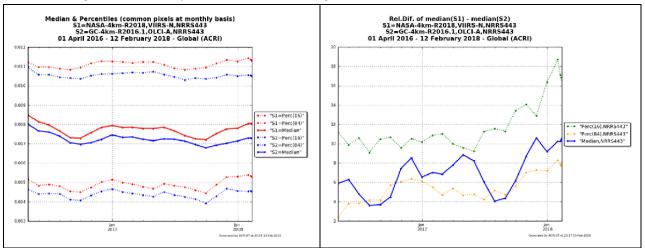


Figure 62: inter-comparison of OLCI and VIIRS global level3 time series. Median and percentile (left), OLCI (blue) versus VIIRS (red). Relative difference (VIIRS-OLCI)/OLCI (right)



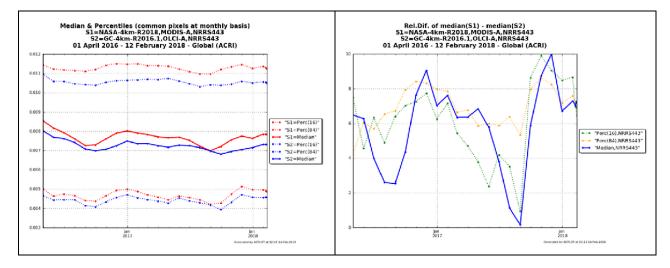
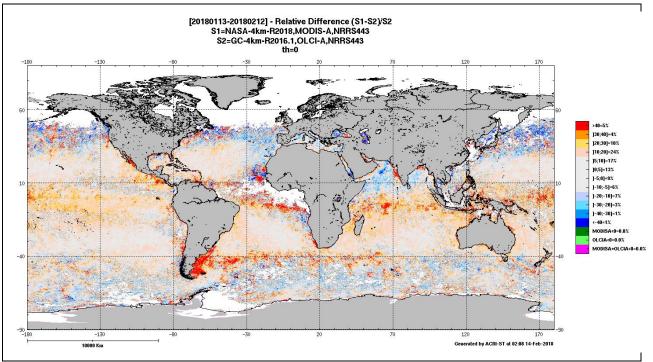


Figure 63: inter-comparison of OLCI and MODIS global level3 time series. Median and percentile (left), OLCI (blue) versus MODIS (red). Relative difference (MODIS-OLCI)/OLCI (right)

Figure 64 below shows that there are strong regional variability of difference when VIIRS and MODIS are compared to OLCI. The largest differences occur in the highly productive regions of the world (ex: Malvinas current and Patagonian shelf, equatorial upwelling etc.



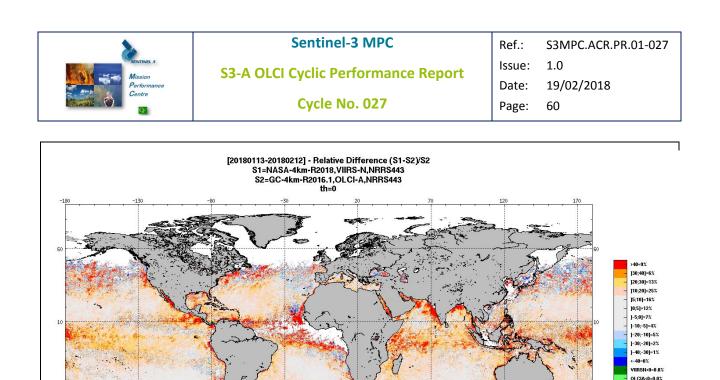


Figure 64: relative difference between MODIS and OLCI (top) and VIIRS and OLCI (bottom) at 443nm.

RSN+OLCIA«

Generated by ACRI-ST at 23:13 13-Feb-2018

5.2.1.3 Summary:

Level 2 product validation against in situ measurements shows very good results up to 560nm. 665nm band shows poor statistics, longer wavelength are not validated due to the lack of in situ data. While 443, 490, 510 and 560nm perform well in both case one and case 2 waters, 412nm and presumably 400nm fall within accuracy requirement in case 1 waters only.

Inter-comparison with contemporaneous missions shows strong seasonal bias with better agreement in the northern hemisphere summer and strong regional variability.

5.2.2 Validation against in-situ data at Southern California AERONET SeaPRISM Eureka platform (USC)

I-Used Datasets

Three S3A/OLCI L2-WFR products over the Southern California AERONET SeaPRISM Eureka platform (USC) close to the US Pacific Coast in 2017 were retrieved from the Copernicus Online Data Access web page, and are used in this analysis (listed below).

OLCI data around USC site



- S3A_OL_2_WFR____20170718T175211_20170718T175511_20170720T015410_0179_020_098
 _2340_MAR_O_NT_002.SEN3
- S3A_OL_2_WFR___20170729T180709_20170729T181009_20170729T200325_0179_020_255 _2340_MAR_O_NR_002.SEN3
- S3A_OL_2_WFR____20171026T175940_20171026T180240_20171028T015159_0179_023_369
 _2340_MAR_O_NT_002.SEN3

The AERONET-OC measurements from the Southern California AERONET SeaPRISM Eureka platform (USC) site have been used. The instrument is mounted on the oil platform Eureka (33.5637° N, 118.1178° W), which is located 18 km off the coast of Newport Beach, California (Figure 65).

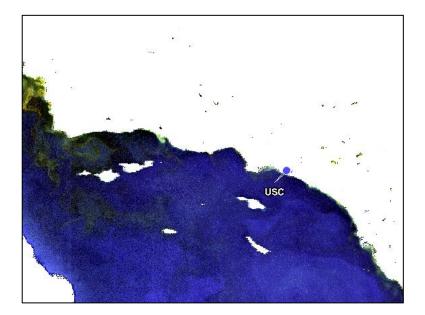


Figure 65: Location of the USC site.

II-Methods

Comparisons were made using the OLCI L2-WFR products and AERONET-OC in-situ measurements for normalized water-leaving reflectance (ρ_{WN}). The selection of OLCI L2-WRF products was restricted to images showing clear skies and filtered for contamination. The following flags were applied to all products: WQSF_lsb_cloud, WQSF_lsb_cloud_margin, WQSF_lsb_cloud_ambiguous, WQSF_lsb_cosmetic, WQSF_lsb_saturated, WQSF_lsb_suspect_hisolzen, WQSF_lsb_highglint and WQSF_lsb_snow_ice [Recommended by S3VT]. For each band, the normalized water-leaving reflectance was filtered using invalid retrieval flag RWNEG_b. The AERONET-OC level 1.5 measurements have been used in this report. The AERONET-OC measurements have been selected as the closest in time to Sentinel-3A overpasses. Regarding OLCI-L2-WFR products, macro-pixels are used as 5x5 pixels average over the USC site . For the matchup analysis, data products were evaluated through the scattering and |RDP|, the bias as absolute relative percent difference

$$|RDP| = \frac{1}{N} \sum_{i=0}^{N} \frac{|y_i - x_i|}{|x_i|} \cdot 100\%$$

Where y_i is OLCI $\rho_{WN}\left(\lambda\right), x_i$ is the in-situ $\rho_{Nw}\left(\lambda\right),$ and N the number of samples.

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III-Preliminary results

As noticeable in Figure 66, OLCI L2 estimations of ρ_{WN} show behaviors similar to the in-situ measurement of USC. OLCI tend to overestimate the value of ρ_{WN} around USC. The reflectance peaks around 490nm, feature associated with relatively turbid waters [Melin & Vantrepotte 2015]. USC is located off the shelf in the Southern California Bight with deep waters (200m), a region of the North American West Coast characterized by a subarctic offshore current flowing south, and a subtropical nearshore current flowing North. Those currents are responsible for the oligotrophic waters in this area, with a high content of organic and inorganic suspended particles [Lin et al 2009, Legaard & Thomas, 2006]. The related total suspended matter concentration in the area is shown in Figure 69.

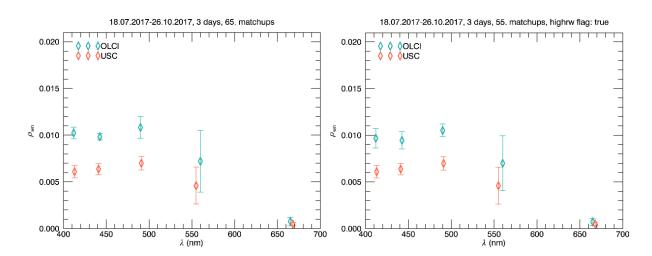


Figure 66: Normalized water leaving-reflectance (ρ_{WN}) averaged over 3 days, comparing OLCI to the in-situ measurements from USC on the 18 & 29/07, 26/10 of 2017. Bottom: OLCI flag WQSF_lsb_HIGHRW raised.

OLCI is overestimating the value of ρ_{WN} compared to USC in-situ measurement, as noticeable in Figure 66. The global overestimation is confirmed by the regression plot in Figure 67, which shows an important slope of OLCI's estimations. The |RDP| values shown in Figure 69, reach maxima of 41 % at 412 nm .



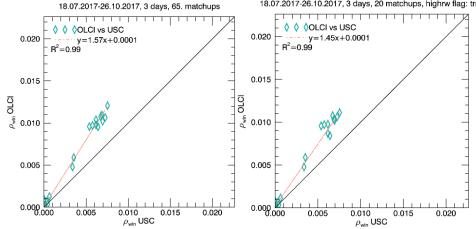


Figure 67: Regression plots of ρ_{WN} (OLCI/InSitu) over the 5x5 pixels matchups for USC on the 18 & 29/07, 26/10 of 2017 . Right: OLCI flag WQSF_lsb_HIGHRW is raised.

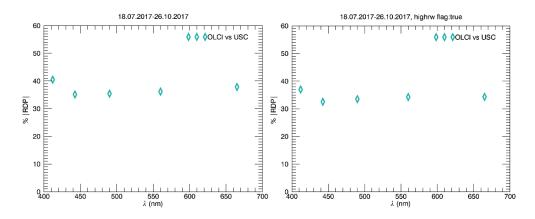


Figure 68: Absolute relative percent difference of OLCI L2 ρWN estimations with in-situ measurements from USC on the 18 & 29 /07, 26 /10 of 2017. Right: OLCI flag WQSF_lsb_HIGHRW is raised.

The differences between OLCI and in-situ measurements in this area can result from a combination of systematic effects in the in-situ measurements as well as inaccuracies in the algorithms used to build L2 OLCI products [S3 handbook]. In particular, in this coastal area, discrepancies at short wavelengths are likely to be linked with adjacency effects and limitations of the validity of the aerosol models and atmospheric correction algorithms. Indeed, the local aerosols may not be well represented by the operational aerosol model, as optically complex waters may trigger components of the atmospheric process [Franz et al 2007]. In addition, the adjacency effects are also expected, due to the high albedo of the nearby mainland with respect to that of the sea, likely to lead to overestimations in both satellite and in-situ data products [Zibordi et al 2009].

The impact of the WQRF_lsb_HIGHRW flag, triggering the cases 1 and 2 water processors, has been also considered. Indeed, in coastal areas, processing data with case 1 or 2 water dedicated algorithms

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can have a strong impact [Melin & Vantropotte 2015]. The percent of pixels where the flag is raised is shown in Table -6, reaching 85% on average. The impact of the WQRF_lsb_HIGHRW flag on the averaged ρ_{NW} values for OLCI can be noticed in Figure 66. At 412 nm, the averaged value of ρ_{NW} is reduced for OLCI when the flag WQRF_lsb_HIGHRW is raised.

The |RDP|, appearing in Figure 68 is slightly reduced from 41 to 37 % at 412 nm when considering only the pixels where the WQRF_lsb_HIGHRW flag is raised. Figure 69 shows the high values of the total suspended matter content with high peak along the coast, consistent with case 2 water [*Zibordi et al 2009a*].

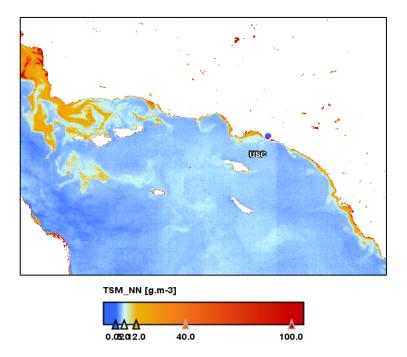


Figure 69: Total suspended matter concentration, estimated from OLCI L2 around USC on the 26/10/2017



Table -6: auxiliary data for OLCI around USC location in 2017

Date	% pixels (highrw flag: true)	IWV (kg.m ⁻²)	TSM (g.m⁻³)	A865	T865	Ch. NN (mg.m⁻³)	Ch. OC4Me (mg.m ⁻ ³)	Ch. In-situ (mg.m ⁻³)
18.07.2017	57	36.7	1.1	0.5	0.2	0.5	3.0	1.6
29.07.2017	100	39.7	0.4	1.3	0.05	0.2	0.6	0.4
26.10.2017	100	18.5	0.7	1.4	0.05	0.1	0.5	0.5

Table 7: auxiliary data for OLCI around USC location in 2017

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

The latest OLCI L2WLR products (available on CTCP in directories /mount/data3/REP_006_OL1 [L1] and /mount/data2/REP_006_OL2 [L2]) have been analysed using a "self-consistency" method. This method has also been applied to the Polymer level 2 products for comparison.

This method, described in <u>https://www.eposters.net/poster/consistency-analysis-of-ocean-color-products-at-high-latitudes</u>, consists in using multiple daily observations in the Arctic, in summer, to assess how the atmospheric correction is affected by increasingly high optical lengths : (1) each ocean point in the Arctic can be observed several times per day due to overlapping orbits, (2) time difference is less than 12 hours; natural variations of the ocean reflectance can be neglected (3) water reflectances are, when available, fully normalized, thus should be independent of the observation geometry, (4) analysis performed in terms of air mass, $m^*=1/cos(sza)+1/cos(vza)$, (5) this method allows assessing biases at high latitudes without requiring in-situ data.

This method is illustrated on the following figure, where the red rectangle illustrates an area suitable for comparing two overpasses:

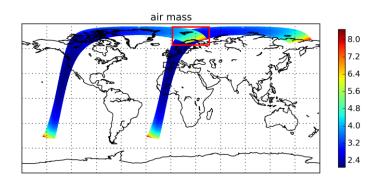


Figure 70: Illustration of the comparison of the water reflectances retrieved under various geometry conditions (air mass) in the same day, in the Arctic region.



Data from June 10 to 20, 2017, have been used.

The software and flagging configuration is as follows:

- OLCI-L2WLR: using IPF 06.09, with flags INVALID, LAND, CLOUD, SNOW_ICE, INLAND_WATER, TIDAL, COSMETIC, SUSPECT, SATURATED, MEDGLINT, HIGHGLINT, WHITECAPS, ADJAC, AC_FAIL, BPAC_ON, WHITE_SCATT, LOWRW, HIGHRW (not HISOLZEN). The water reflectance (OaXX_reflectance) have been used. These products are not normalized to nadir-nadir observation, which is not ideal in this context. However, performing this normalization would not compensate for the strong directional effects that are being observed.
- Polymer: version 4.2 has been used, with the following flags applied: CLOUD (Polymer), INVALID, NEGATIVE_BB, OUT_OF_BOUNDS, EXCEPTION, THICK_AEROSOLS

We show the difference between the water reflectance observed at a given air mass, and the water reflectance observed at the lowest daily air mass. The results are shown at 412 nm on the following figure:

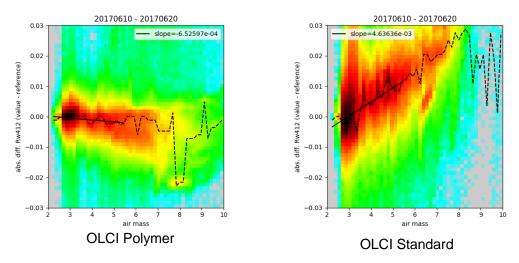


Figure 71: self-consistency results of OLCI Rw412 products. Each plot shows the variation of the water reflectance with the reference observation (the observation at minimal air mass) from the same day. The slope of the fit gives the dependency of Rw412 on the air mass.

We can see a strong increase of the estimated water reflectance for the standard OLCI product, but not for Polymer. The slope of the regression is used as an indicator of the trend. This slope is summarized at all spectral bands on the following figure:

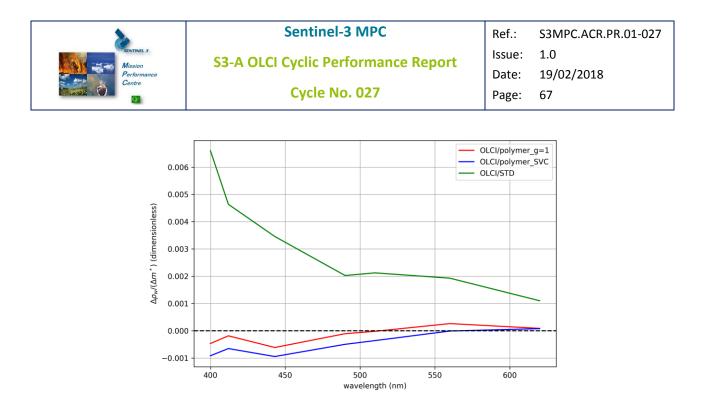


Figure 72: Summary of the self-consistency slopes (see previous figure) for each band, and for each product.

On this figure, we also show the effect of not applying system vicarious calibration gains for Polymer, which only slightly affects the results.

An example of two level 2 products overpassing the same area (Norwegian Sea, 20170613) is shown on the following figure, which highlight the trend previously illustrated.

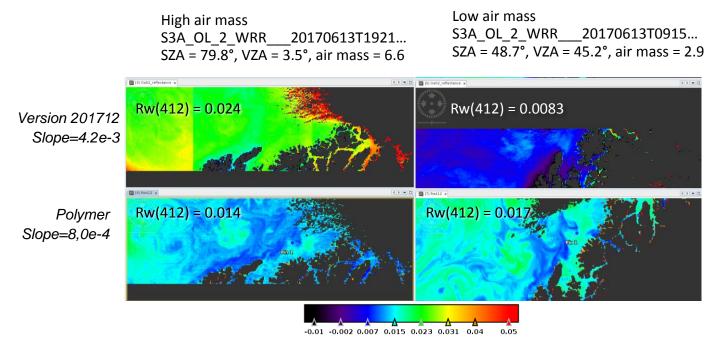


Figure 73: Image of water reflectances at 412 nm retrieved under various geometry conditions (high (left) and low (right) air mass) for the same day (13/06/2017), in the Norwegian Sea region.

These results indicate that the **standard OLCI products are strongly positively biased in high air mass conditions**.



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

Please refer to section 4.2, reporting on Cloud Screening over both Land and Water surfaces.

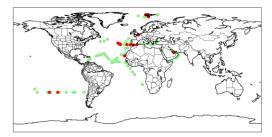
5.5 [OLCI-L2WLR-CV530] Validation of Aerosol Product

To validate OLCI's Aerosol product (aerosol optical thickness and Angstroem coefficient at 865nm), we continuously compare it with data from AERONET (Holben et al 1998), AERONET-OC (Zibordi et al 2009) and MARITIME AERONET (Smirnow et al 2009). This is an ongoing process, where co-located data are collected and analysed. Only quality assured L2 AERONET is used. All OLCI-L2 ocean product types have been validated: full resolution and reduced resolution (*wrr, wfr*); near real time and non time critical (*NR, NT*). The ocean colour products have been taken from Eumetsats CODA (Copernicus Online Data Access) website. Although the following quantitative comparisons are restricted to *reduced resolution non time critical*, the found results are valid for all product types.

5.5.1.1 AERONET comparisons



3800 OLCI scenes within the period of June 2017 to January 2018 have been analysed so far. For a matchup, the temporal distance between the satellite overpass and the AERONET acquisition was less than 60 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. Due to the fact, that most of the AERONET stations are on land, the number of matchups reduced from 950 co-locations to 4 only, too few for a quantitative comparison up to now. The 135 AERONET maritime aerosol network co-locations, acquired during ship cruises, evolved to 17 matchups, shown in Figure 75. Here the agreement of the aerosol optical thickness at 865nm is very high (linear correlation of 0.97), no systematic bias is found and the root mean squared distance is 0.02. The Angstrom coefficients from AERONET and OLCI are not directly comparable, since they belong to different wavelength ranges AERONET: 870nm- 440nm, OLCI: 865nm - 779nm). Nevertheless, there is a positive correlation of 0.36 and a root mean squared distance of 0.33.

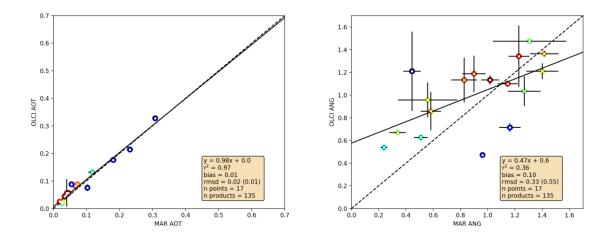


Figure 74: Left: OLCI aerosol optical thickness at 865nm against Aeronet maritime aerosol network optical thickness at 870nm, right: OLCIs Angstroem exponent at 865nm-779nm against the Aeronet Angstroem exponent at 865nm-440nm. The error-bars represent the standard deviation within the 10x10km² OLCI scene, and the uncertainty of the AERONET product, respectively. The data covers the period from June 2017 – January 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).



5.5.1.2 Summary

The validation of OLCI aerosols products shows a promising high agreement for the aerosol optical thickness (*rmsd* < 0.02). The Angstroem Exponent agrees with less accuracy ($r^2 = 0.35$, *rmsd* = 0.33). However, the very low number of matchups prevents final evaluation.

5.5.1.3 References

- Holben, B. N., et al., AERONET—A federated instrument network and data archive for aerosol characterization, Remote Sens. Environ.,66, 1–16, 1998.)
- Smirnov, A., Holben, B.N., Slutsker, I., Giles, D.M., McClain, C.R., Eck, T.F., Sakerin, S.M., Macke, A., Croot, P., Zibordi, G., Quinn, P.K., Sciare, J., Kinne, S., Harvey, M., Smyth, T.J., Piketh, S., Zielinski, T., Proshutinsky, A., Goes, J.I., Nelson, N.B., Larouche, P., Radionov, V.F., Goloub, P., Krishna Moorthy, K., Matarrese, R., Robertson, E.J., Jourdin, F., 2009. Maritime aerosol network as acomponent of aerosol robotic network. J. Geophys. Res. 114, 1–10, http://dx.doi.org/10.1029/2008JD011257.
- Zibordi G., B.Holben, I.Slutsker, D.Giles, D.D'Alimonte, F.Mélin, J.-F. Berthon, D. Vandemark, H.Feng,G.Schuster, B.Fabbri, S.Kaitala, J.Seppälä. AERONET-OC: a network for the validation of Ocean Color primary radiometric products. Journal of Atmospheric and Oceanic Technology, 26, 1634-1651, 2009.

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

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. Above land it is performed via comparisons with ground based GNSS (Ware et al 2000) measurements and water vapour from AERONET (Holben et al 1998, Perez-Ramirez et al 2014). Above Ocean a verification using AERONET, AERONET-OC (Zibordi et al 2009) and AERONET Maritime Aerosol Network (Smirnow et al 2009) has been performed, but the amount of matchups is low.

All L2 product types have been validated: full resolution and reduced resolution, near real time and non time critical, Ocean Colour (*wrr, wfr*) and Land Colour (*Irr, Ifr*). The ocean colour products have been taken from Eumetsats CODA (Copernicus Online Data Access) website, the land colour products have been taken from ESAs Copernicus open access hub website.

The found results for all product types are identical, as expected, since the used processor is the same. The following quantitative comparisons are hence restricted to *wrr NT* (Ocean Colour Product, reduced resolution, non time critical). Since the ocean colour product and the land colour product provide water vapour above land **and** water surfaces, the comparison is comprehensive.

6.1 Integrated water vapour above land

6.1.1 Comparison with GNSS

The OLCI integrated water vapour above land has been validated via global GNSS (Ware et al. 2000) measurements. 3800 OLCI scenes within the period of June 2017 to January 2018 have been analysed. The OLCI observations comprise very humid air-masses at the equator and very dry and cold atmospheres above the Rocky Mountains and polar regions. The scenes cover high and low elevations. The temporal distance between the satellite overpass and the GNSS acquisition was less than 30 min. Only OLCI measurements are used for the validation which are cloud-free in an area of about 10 km around the GNSS stations. This reduced the number of matchups from 70000 to 10000. For the cloud detection, the standard L2 cloud-mask (*cloud, cloud margin and cloud ambiguous*) has been applied. No more flags have been applied. Since the majority of GNSS station are located in North America and, further, the last winter there was extremely cold, the comparison is biased towards dry conditions. Figure 75 shows the scatter plot of the corresponding water vapour products, the colour coding indicates the number density of cases. The agreement between both datasets is high (linear correlation of 0.95). However, a systematic wet bias of 10% is found. The bias corrected root mean squared distance is 2.4 kg/m².



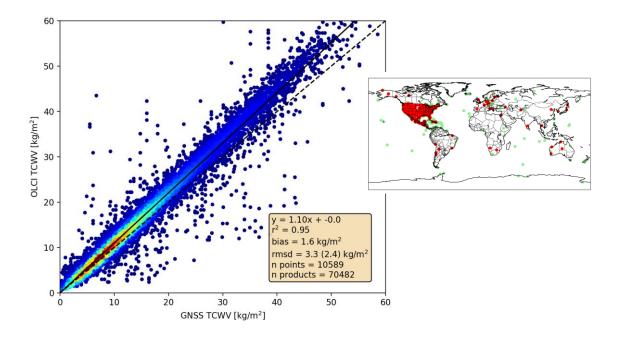


Figure 75: Normalized frequencies of occurrence for comparisons of OLCI-derived IWV against GNSS data, for the period June 2017 – January 2018. The geographic location of the GNSS stations is shown in the right (red spots have been used, green spots have been filtered).

6.1.2 Comparison with AERONET

A further step in the validation process is realised by using IWV, derived from spectral AERONET measurements (Holben et al 1998 Perez-Ramirez et al 2014). 3800 OLCI scenes within the period of June 2017 to January 2018 have been analysed. Solely AERONET *level2* products have been used which are cloud screened and quality assured.

As for the comparison with GNSS, only OLCI measurements are used for the validation which are cloudfree in an area of about 10 km around the GNSS stations. This reduced the number of matchups from 950 to 255. For the cloud detection, the standard L2 cloud-mask (*cloud, cloud margin and cloud ambiguous*) has been applied. Figure 76 shows the scatter plot of the corresponding water vapour products, the colour coding indicates the number density of cases. The agreement between both datasets is high (linear correlation of 0.98). As for the comparison with GNSS, a systematic wet bias is of 13% is found. The bias corrected root mean squared distance is 1.6 kg/m², which is slightly better than for the comparison with GNSS. A probable reason is the inherent and very strict cloud filtering of the AERONET L2 data.



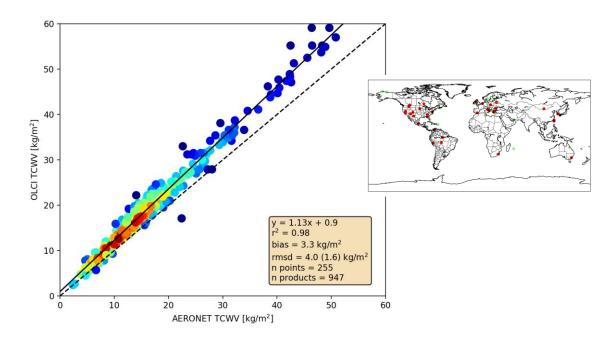


Figure 76: Normalized frequencies of occurrence for comparisons of OLCI-derived IWV against AERONET data, each for the period June 2017 – January 2018. The geographic location of the used AERONET stations is shown in the right (red spots have been used, green spots have been filtered).

6.2 Integrated water vapour above water

6.2.1 Comparison with GNSS

Some of the used GNSS stations are located at the coast, on islands or close to inland waters. These stations have been used for a quantitative comparison. The temporal distance between the satellite overpass and the GNSS acquisition was less than 30 min. Only OLCI measurements are used for the validation which are cloud-free in an area of about 10 km around the GNSS stations. Only stations have been used which are closer than 2 km to cloud free water pixels. This reduced the number of matchups from 70000 to 700. For the cloud detection, the standard L2 cloud-mask (*cloud, cloud margin and cloud ambiguous*) has been applied. *Figure 77* shows the scatter plot of the corresponding water vapour products, the colour coding indicates the number density of cases. The agreement between both datasets is much lower than above land (linear correlation of 0.66). Further many points show a large wet bias. Eventually, the scattering is much larger, the bias corrected root mean squared distance (*rmsd*) is 8 kg/m².



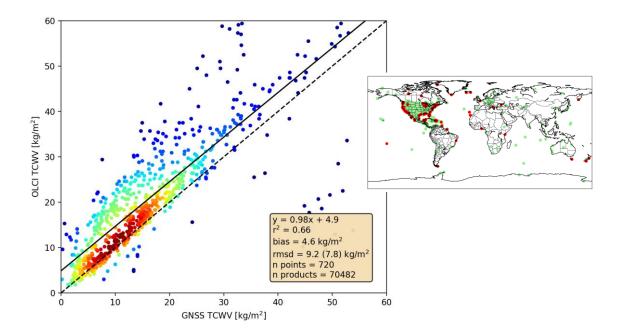


Figure 77: Normalized frequencies of occurrence for comparisons of OLCI-derived IWV against GNSS data, each for the period June 2017 – January 2018. The geographic location of the GNSS stations is shown in the right (red spots have been used, green spots have been filtered).

6.2.2 Visual inspection

A number of OLCI L2 IWV scenes have been visually inspected and analysed for the ocean retrieval. A scene above the Pacific Ocean is shown in Figure 78 and discussed herein in some detail. OLCI IWV is compared with the IWV from ECMWF analysis. It should be mentioned, that water vapour above Ocean from Model-analysis is already of high quality and in particular it is bias free. Small spatial features may be not be reflected precisely or located on the wrong spots, but the total amount is correct in average.

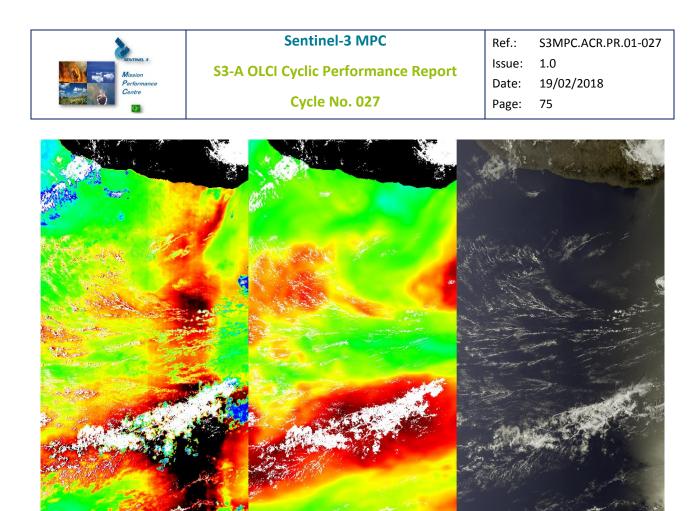


Figure 78: IWV, estimated from OLCI at 03/March/2017, above the Pacific, south-west of Baja California. Left: IWV from OLCI, middle: ECMWF Analysis, right: RGB. The colour coding ranges from 1 kg/m2 (blue) to 60 kg/m2 (black). Land and clouds are masked out (black and white, resp.)

The most prominent artefact is the huge overestimation of water vapour in the transition between the glint and off glint region. Further, an underestimation (blue spots on the east side) above undetected clouds is perceivable. All other features are represented and the amounts are in agreement.

6.3 Summary

The validation exercise of the OLCI IWV product demonstrates that the product is of high quality (bias corrected root mean squared distance of ~ 2kg/m²) for retrievals above land surfaces. But there is a systematic overestimation of 10% to 13%. The comparison with GNSS stations close to water show a larger wet bias for the ocean retrievals. In particular retrievals above ocean show an overestimation in transition zones between glint and off glint.



7 Level 2 SYN products validation

7.1 [SYN-L2-CV-100]

7.1.1 SY_2_SYN Aerosol products and Surface Directional Reflectance

7.1.1.1 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.

7.1.1.2 Results

Validation started when a first version of products with sufficient quality was produced within S3 MPC and delivered on 22th December 2017. It consisted of 1 week of global data. The data analysis is far from optimal because:

- Of the large data volume to handle
- Matchups with AERONET have to be done by ESL
- There is no link with corresponding L1 OLCI and L1 SLSTR, and thus difficulties to perform independent atmospheric correction, i.e. the key point to validate the surface reflectance SYN product
- The image reading within the SNAP environment is very long: a SYN2 orbit file took more than 10 minutes to open.

We first investigate AOT product, the most critical parameter.

- We looked at numerous flags and try find several combination of them select 'good' quality AOT products. We give an example of the product on Figure 79 with a first flag combination selection in order to filter out outliers. The overall feeling about the product is that the global coverage and the value range is correct but with obvious outliers, dubious spatial patterns and resisual cloud contamination. We focus after on pixels for which the SYN 2 specific flags combination is valid: !SYN.CLOUD & !SYN.PARTLY_CLOUDY & SYN.SUCCESS.
- A regression analysis of SYN 2 AOT with Aeronet coincident measurements was done for the whole test data set (1 week global). The location of the matchups is shown on Figure 80. After the selection of the good pixels, the cloud free matchups number is reduced from 155 to 53. The



regression plots are shown in Figure 81. The correlation with AOT AERONET has improved and it gets closer to quality standard for a best combination of flags, but it is at the cost of spatial cover and there is a very large bias (~0.2) and RMS (~0.3). It is clear that some cloud contamination remains.

- The AOT retrieval is done using a unique Aerosol model. That might be OK for use in atmospheric corrections but it is less acceptable for an aerosol product.
- The uncertainty attached to the AOT exhibits unrealistic values.

Analysis of the Surface Directional Reflectances has just started, some spectra look realistic (see Figure 82), but:

- Unflagged outliers remain, as the behaviour of the flag SYN.SDR_OOR, which should detect out of range SDR, is dubious.
- The uncertainty attached to the SDR exhibits unrealistic values, and lots of NaN.
- For making progress in the SDR validation, it is mandatory to have child products, or directly NetCDF extraction of AOT, SDR's, L1B OLCI and SLSTR of 50x50 boxes around AERONET stations.

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Figure 79: Example of SYN 2 orbit product over Sahara and Europe on 1st November 2016. (left) Surface Directional Reflectance (SDR) in OLCI band 1. (Middle) SDR in SLSTR band 1 Nadir. (Right) two AOT maps at 550 nm, one without and one with a white semi-transparent white mask added, selecting only pixels for which the SYN 2 specific flags combination is valid : !SYN.CLOUD & !SYN.PARTLY_CLOUDY & SYN.SUCCESS



Sentinel-3 MPC

S3-A OLCI Cyclic Performance Report

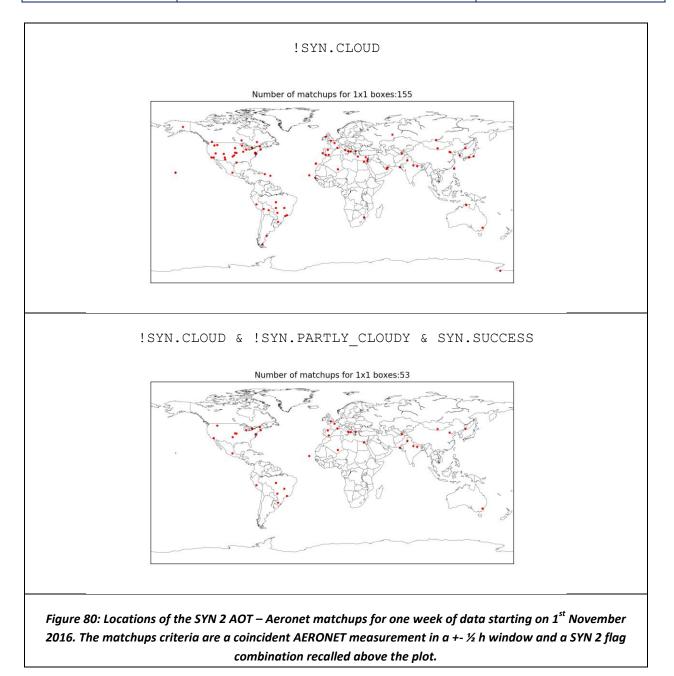
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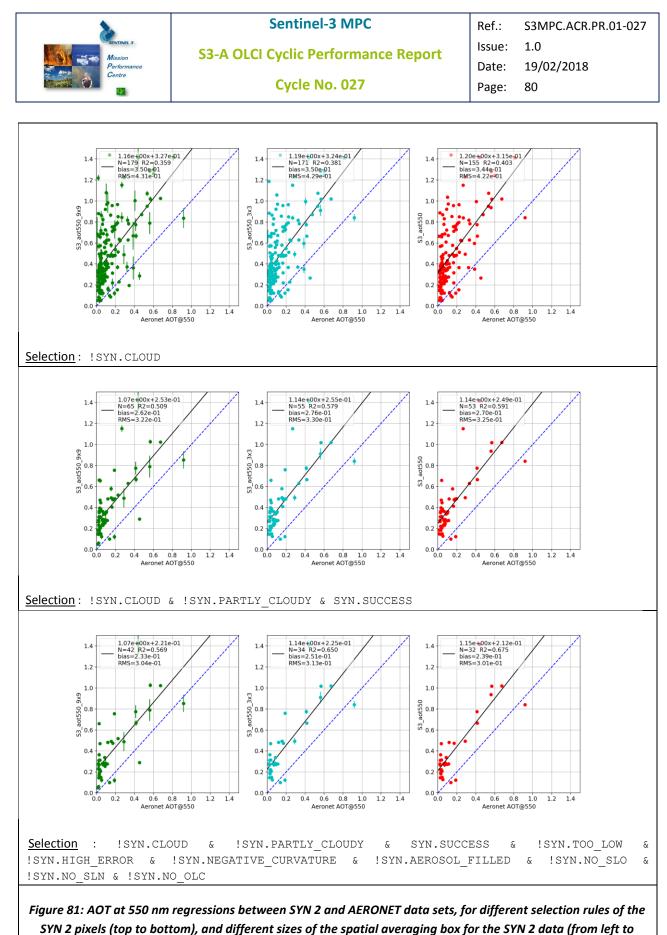
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 Date:
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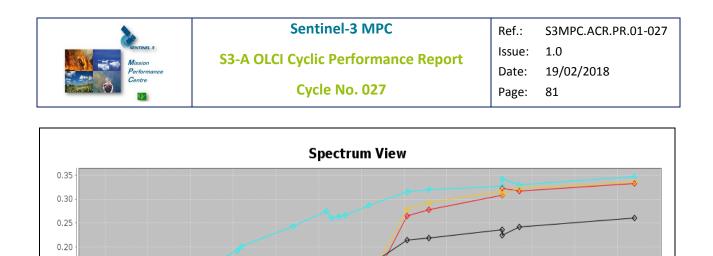
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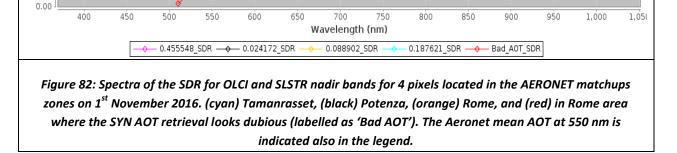






right : 9x9, 3x3 and 1x1 pixels boxes)





7.1.2 SY_2_VGP: consistency checks with PROBA-V Level2A

Preliminary consistency analysis was performed on a limited set of SY_2_VGP and PROBA-V Level2A segments.

7.1.2.1 Data and methods

0.15 0.10 0.05

Three S3A_SY_2_VGP segments were selected for the analysis (Table 8). For each of the segments, the corresponding PROBA-V Level2A segment was chosen. In all three cases, the S3A_SY_2_VGP segment overlaps with the 875 km wide swath of the right PROBA-V camera, which is tilted westwards, as is the case for OLCI. The viewing angles are therefore not expected to differ considerably, but this was not (yet) verified.

The S3A_SY_2_VGP status map shows very large areas with "SM.ice_or_snow = true". The status map was therefore not used to exclude pixels from the analysis. For PROBA-V L2A the status map was interpreted in order to exclude pixels labeled as cloud, snow/ice or water, or with bad radiometric quality or bad coverage in one of the spectral bands.

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Table 8 Data used in the analysis

	Sentinel-3	PROBA-V
Segment	Reprocessed SYN data (IPF baseline 2.26, dd. 06/12/2017)	Collection 1, Level 2A
Oceania	S3A_SY_2_VGP20161102T004347_20161102T012804_20	PROBAV_L2A_20161102_01
	171209T024702_2657_010_259LR1_R_NT_002.SEN3	2206_3_1KM_V102
Asia	S3A_SY_2_VGP20161101T061252_20161101T065709_20	PROBAV_L2A_20161101_06
	171209T023146_2657_010_248LR1_R_NT_002.SEN3	2727_3_1KM_V102
North America	S3A_SY_2_VGP20161107T170417_20161107T174834_20	PROBAV_L2A_20161107_17
	171211T235219_2657_010_340LR1_R_NT_002.SEN3	4339_3_1KM_V102

The geometric mean regression (GMR) model, i.e. an orthogonal regression model, is used to identify the relationship between the S3A_SY_2_VGP and the PROBA-V L2A TOA reflectances, because both data sets are subject to noise (Ji and Gallo, 2006). The GMR model minimizes the sum of the products of the vertical and horizontal distances (errors on Y and X) and is of the form

$$Y = a + b \cdot X \tag{1}$$

with slope

$$b = sign(R)\frac{\sigma_Y}{\sigma_X} \tag{2}$$

and intercept

$$a = Y - b \cdot X \tag{3}$$

The σ_X and σ_Y are the standard deviations of X and Y, R is the correlation coefficient, and sign) is the signum function that takes the sign of the variable between the brackets.

The coefficient of determination (R^2) indicates agreement or covariation between two data sets with respect to a linear regression model, summarizing the total data variation explained by this linear regression model.

$$R^{2} = \left(\frac{\sigma_{X,Y}}{\sigma_{X} \cdot \sigma_{Y}}\right)^{2} \tag{4}$$

with $\sigma_{X,Y}$ the co-variation of X and Y. A disadvantage of R² is that it only measures the strength of the relationship between the data, but gives no indication if the data series have similar magnitude (Duveiller et al., 2016).

The Root Mean Squared Difference (RMSD) measures how far the difference between the two data sets deviates from 0 and is defined as:



$$RMSD = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (X_i - Y_i)^2}$$
(5)

The RMSD expresses the overall difference, including random and systematic differences, in the same unit as the datasets themselves, i.e. % (TOA reflectance). The random and systematic differences are derived from the mean squared difference (*MSD*), defined as:

$$MSD = \frac{1}{n} \sum_{i=1}^{n} (X_i - Y_i)^2$$
(6)

The *MSD* is further partitioned into the systematic mean product difference (MPD_s) and the unsystematic or random mean product difference (MPD_u) , i.e. how much of the difference between X and Y is not 'explained' by the GMR model (Willmott, 1981). In order to be comparable to the RMSD in terms of magnitude, the root of the systematic and unsystematic mean product difference is used $(RMPD_s \text{ and } RMPD_u)$:

$$RMPD_{u} = \sqrt{MPD_{u}} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (|X_{i} - \hat{X}_{i}|)(|Y_{i} - \hat{Y}_{i}|)}$$
(7)

with \hat{X}_i and \hat{Y}_i estimated using the GMR model fit and n the number of samples. Then,

$$RMPD_s = \sqrt{MSD - MPD_u} \tag{8}$$

The partitioning of the difference into systematic and unsystematic difference provides additional information to the RMSD on the nature of the difference between two data sets.

The Mean Bias Error (MBE) measures the average actual difference between two data sets and positive and negative differences between observations, and is defined as:

$$MBE = \frac{1}{n} \sum_{i=1}^{n} (X_i - Y_i) = \bar{X} - \bar{Y}$$
(9)

Although the MBE is not the best way to estimate the bias, it is used here because it retains the sign of the difference between the data sets, unlike the other metrics.

7.1.2.2 Results and discussion

Visual checks on the available S3A_SY_2_VGP products (20161101-20161107) showed that:

Many segments show (very) little data content, with large areas labelled as 'NaN' in the spectral bands.



- Most pixels are labelled as 'ice_or_snow' in the SM (brown areas in Figure 83).
- The SM shows for most pixels a combination of 'ice_or_snow' and 'undefined', which is ambiguous.
- The 'NaN' pixel flagging in the spectral bands is unrelated to the information stored in the SM. It is not clear what is triggering the use of 'NaN' in the spectral bands, but it seems related to cloud or snow masking. TOA reflectance values should be available for pixels, regardless of clouds or snow cover (as is the case for SPOT-VEGETATION And PROBA-V). This allows the user to e.g. apply its own cloud/snow detection algorithms or perform analysis over snow pixels.

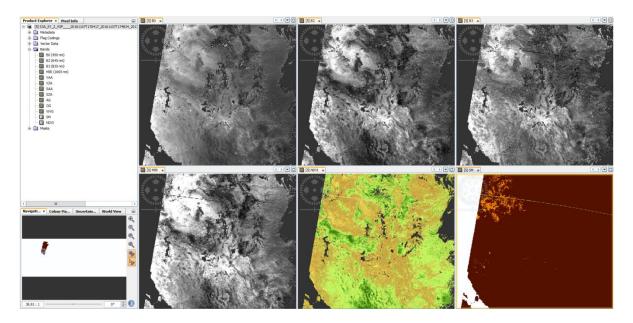


Figure 83 Visual checks on S3A_SY_2_VGP over the North America scene: 4 spectral bands, NDVI and SM (Brown = 254 = 1111 1110 = all 4 bands good quality, land, ice_or_snow, undefined; Orange = 250 = 1111 1010 = all 4 bands good quality, land, undefined; Green = 232 = 1110 1000 = bad SWIR, land, clear).

Figure 84 shows the results of geometric mean regression over the 3 segments and for the 4 spectral bands. Statistical analysis is summarized in Table 9.

For Blue, Red and NIR, correspondence is relatively high, with regression slopes close to 1, regression intercepts close to 0 and thus low systematic differences are found (below 3 %). The unsystematic differences (i.e. scatter around the regression line) are largest for the North America scene (around 5 %), possibly related to undetected clouds or snow, causing some scatter in the regression plots. The MBE fluctuates between positive and negative values, but remains in the range [-0.03; +0.02]. It is to be noted that differences might also be caused by different illumination conditions, related to different overpass times between S3A and PROBA-V: in November/2016, the equator local overpass time of PROBA-V was around 10:41 a.m., while the overpass time of S3A is 10:00 a.m.

In contrast, the SWIR band shows very large systematic difference, with regression slopes in the range [1.4; 1.6] and systematic differences up to 17 % reflectance. The MBE is negative and in the range [-0.17;

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-0.13]: the PROBA-V L2A SWIR reflectance is systematically higher than S3 SYN VGP. It is not clear what is causing this discrepancy.

	Table 9 Results of statistical analysis between S3A_SY_2_VGP and PROBA-V L2A TOA reflectances								
	Segment	GMR	GMR	R ²	MBE	RMSD	RMPDs	RMPDu	N
		intercept	slope	n	K IVIDE	RIVISD	NIVIP DS	RIVIPDU	IN
Blue	Oceania	0.069	0.640	0.49	-0.018	0.024	0.020	0.013	1178400
	Asia	0.038	0.962	0.70	-0.030	0.034	0.030	0.015	445455
	N. America	-0.019	0.983	0.54	0.023	0.054	0.023	0.049	188031
Red	Oceania	0.023	0.884	0.61	-0.003	0.030	0.006	0.029	1179641
	Asia	0.041	0.880	0.81	-0.012	0.023	0.014	0.019	447065
	N. America	-0.015	0.997	0.65	0.016	0.045	0.016	0.042	187386
NIR	Oceania	0.047	0.886	0.45	-0.021	0.043	0.022	0.037	1184469
	Asia	0.044	0.944	0.75	-0.030	0.037	0.030	0.022	447843
	N. America	-0.005	1.006	0.49	0.004	0.050	0.004	0.050	188636
SWIR	Oceania	0.067	1.599	0.48	-0.159	0.167	0.161	0.043	1176405
	Asia	0.082	1.476	0.70	-0.167	0.171	0.168	0.029	480847
	N. America	0.071	1.394	0.59	-0.129	0.138	0.131	0.044	191564

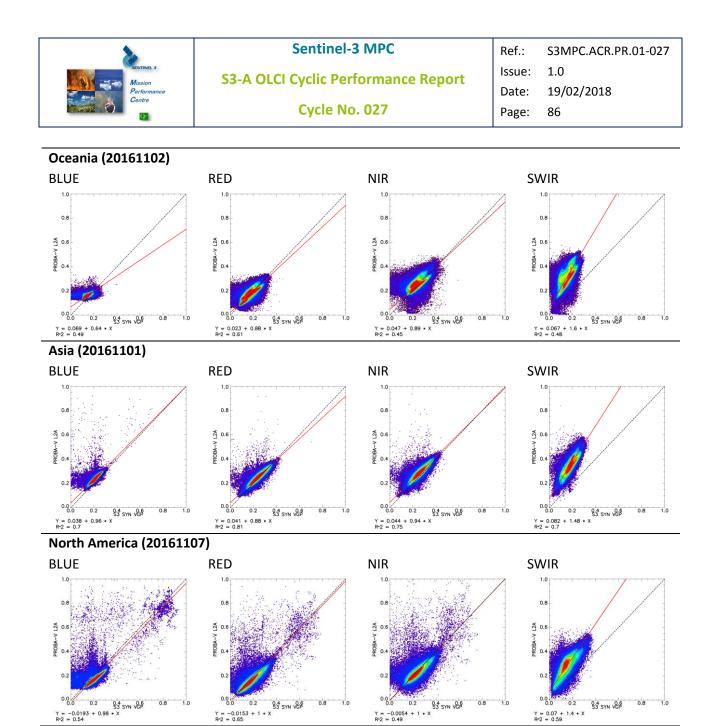


Figure 84 Geometric Mean Regression between S3_SYN_VGP and PROBA-V L2A TOA reflectances over the three segments

Y = -0.0054 + 1 * XR^2 = 0.49

Y = 0.07 + 1.4 * X R*2 = 0.59

7.1.2.3 References

- Duveiller, G., Fasbender, D., Meroni, M., 2016. Revisiting the concept of a symmetric index of agreement for continuous datasets. Sci. Rep. 6, 1–14. doi:10.1038/srep19401
- Ji, L., Gallo, K., 2006. An agreement coefficient for image comparison. Photogramm. Eng. Remote Sens. 72, 823-833. doi:10.14358/PERS.72.7.823
- Sterckx, S., Benhadj, I., Duhoux, G., Livens, S., Dierckx, W., Goor, E., Adriaensen, S., Heyns, W., Van Hoof, K., Strackx, G., Nackaerts, K., Reusen, I., Van Achteren, T., Dries, J., Van Roey, T., Mellab, K., Duca, R., Zender, J., 2014. The PROBA-V mission: image processing and calibration. Int. J. Remote Sens.
 - 35, 2565-2588. doi:10.1080/01431161.2014.883094

Y = -0.0153 + 1 * X $R^2 = 0.65$

Willmott, C.J., 1981. On the validation of models. Phys. Geogr. 2, 184–194.





8 Events

Two OLCI Radiometric Calibration Sequences have been acquired during Cycle 027:

- S04 sequence (diffuser 1) on 25/01/2018 04:11 to 04:13 (absolute orbit 10101)
- S05 sequence (diffuser 2) on 25/01/2018 05:52 to 05:54 (absolute orbit 10102)



9 Appendix A

Other reports related to the Optical mission are:

S3-A SLSTR Cyclic Performance Report, Cycle No. 027 (ref. S3MPC.RAL.PR.02-027)

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

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