Technical Note on Quality Assessment for OceanSat-2 OCM (Quarterly report for Q3 2020)

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AMENDMENT RECORD SHEET

The Amendment Record Sheet below records the history and issue status of this document.

ISSUE	DATE	REASON
0.1	27/10/2020	First EDAP version (Report No. 7)
1.0	23/11/2020	Final version implementing ESA feedback

TABLE OF CONTENTS

1. INTRODUCTION

This document is the Q3 2020 (July – September 2020) quarterly Quality Assessment (**QA**) report for the latest Ocean Colour Monitor (**OCM**) instrument, OCM-2, on-board the Indian satellite, OceanSat-2.

This QA report provides a series of product checks, using a sample of OCM-2 products retrieved through ESA's *Online Dissemination service* (*https://tpm-ds.eo.esa.int/socat/OceanSat2/*), that relate to product format consistency as well as product content consistency and quality. This QA report also provides a derivation of product quality statistics.

1.1 Reference Documents

The following is a list of documents with a direct bearing on the content of this report. Where referenced in the text, these are identified as RD.n, where 'n' is the number in the list below:

[RD.1] Oceansat-2 Quarterly Report No.1, IDEAS+-VEG-OQC-REP-2655, Issue 1.0, 05 December 2016.

[RD.2] EDAP Mission Quality Assessment Guidelines, Issue 1.2, 19 July 2019.

[RD.3] Oceansat-2 Quarterly Report No.5, IDEAS+-VEG-OQC-REP-2892, Issue 1.0, December 2017.

[RD.4] EO-SIP Specialisation for OceanSat-2 Mission, EMSS-EOPG-TN-15-002, Issue 1.0, 19 October 2015.

[RD.5] Technical Note on Quality Assessment for OceanSat-2 OCM (Quarterly report for Q4 2018), EDAP.REP.004, Issue 0.2, March 2019.

[RD.6] Natural Earth datasets, accessible at http://www.naturalearthdata.com/

[RD.7] Chauhan *et al.* 2002. Surface chlorophyll a estimation in the Arabian Sea using IRS-P4 Ocean Colour Monitor (OCM) satellite data, *International Journal of Remote Sensing*, 23:8, 1663-1676, DOI: 10.1080/01431160110075866.

[RD.8] DIMITRI Software User Manual, v3.1.1, 20 February 2015.

[RD.9] Technical Note on DIMITRI Quality Assessment for OceanSat-2 OCM (Internal report), EDAP.REP.014, Issue 1.0, January 2020.

[RD.10] Angal *et al.* 2016. Cross-calibration of the Oceansat-2 Ocean Colour Monitor (OCM) with Terra and Aqua MODIS, *SPIE Asia-Pacific Remote Sensing, New Delhi, India* DOI: 10.1117/12.2224046

[RD.11] Zibordi *et al.* 2009. AERONET-OC: A Network for the Validation of Ocean Color Primary Products. *J. Atmos. and Oceanic Technology*. 26: 1634-1651 (DOI:10.1175/2009JTECHO654.1).

[RD.12] Technical Note on Quality Assessment for OceanSat-2 OCM (Quarterly report for Q1 2019), EDAP.REP.005, Issue 0.21, April 2019.

[RD.13] OCM-2 (OCEANSAT-2) LEVEL-2 HDF Data Products Format, v1.4, April 2017.

[RD.14] Preethi Latha *et al.* 2014. Validation of Chlorophyll-a concentrations in the Estuarine Waters of Bay of Bengal using OCM-2 Data: A case study in the Godavari basin, *J. Indian Soc. Remote Sens.*, 42(1): 129-138.

[RD.15] O'Reilly *et al.* 1998. Ocean color chlorophyll algorithms for SeaWiFS. *Journal of Geophysics*, 103: 24937–24963.

[RD.16] Shanthi et al. 2013. Validation of OCM-2 sensor performance in retrieving chlorophyll and TSM along the southwest Bay of Bengal coast, *J. Earth Syst. Sci.,* 122(2): 479–489.

[RD.17] Baret *et al.* 2009. Report on the CEOS Land Product Validation Sub-group Meeting. *The Earth Observer*, 21(6): 26-30.

[RD.18] Bailey, S.W. and Werdell, P.J. 2006. A multi-sensor approach for the on-orbit validation of ocean color satellite data products. *Rem. Sens. Environ*, 102: 12-23.

1.2 Glossary

The following acronyms and abbreviations have been used in this Report.

AMC	Angular Matching Criteria
aod	aerosol optical depth
ATBD	Algorithm Theoretical Basis Document
BOA	Bottom of Atmosphere
CEOS	Committee for Earth Observation Satellites
clo	Chlorophyll-a concentration
dac	depth attenuation coefficient
DIMITRI	Database for Imaging Multi-spectral Instruments and Tools for Radiometric Intercomparison
GAC	Global Area Coverage
HPLC	High Performance Liquid Chromatography
L1	Level 1
L2	Level 2
LAC	Local Area Coverage
LEDs	Light-Emitting Diodes
NPL	National Physical Laboratory
OCM	Ocean Colour Monitor
PUG	Product User Guide
QA	Quality Assessment
QA4EO	Quality Assurance for Earth Observation
QLs	QuickLooks
RAA	Relative Azimuth Angle
RD	Reference Document
SSO	Single Sign-On

SZA	Sensor Zenith Angle
TOA	Top of Atmosphere
tsm	total suspended matter
VZA	Viewing Zenith Angle

2. EXECUTIVE SUMMARY

The aim has been to ensure, principally, that the format and content (i.e. radiance and geophysical data) of OCM-2 products (L1B, L2B and L2C), already available to users, are of suitable quality.

This Quarterly QA report updates the previous reporting to include the daily data acquired during July to September 2020; performed by following the QA process and tools (e.g. QA scripts) detailed in [RD.1] and since improved upon within successive EDAP reports.

The aim is to improve the quarterly reporting continually.

2.1 EDAP Quality Assessment

An assessment has been performed using the National Physical Laboratory (**NPL**) EDAP guidelines [RD.2], with the summary reported in

Figure 2-1 and detailed analysis within Section 3. With each iteration of this report, the available documentation has been checked and updated where necessary.

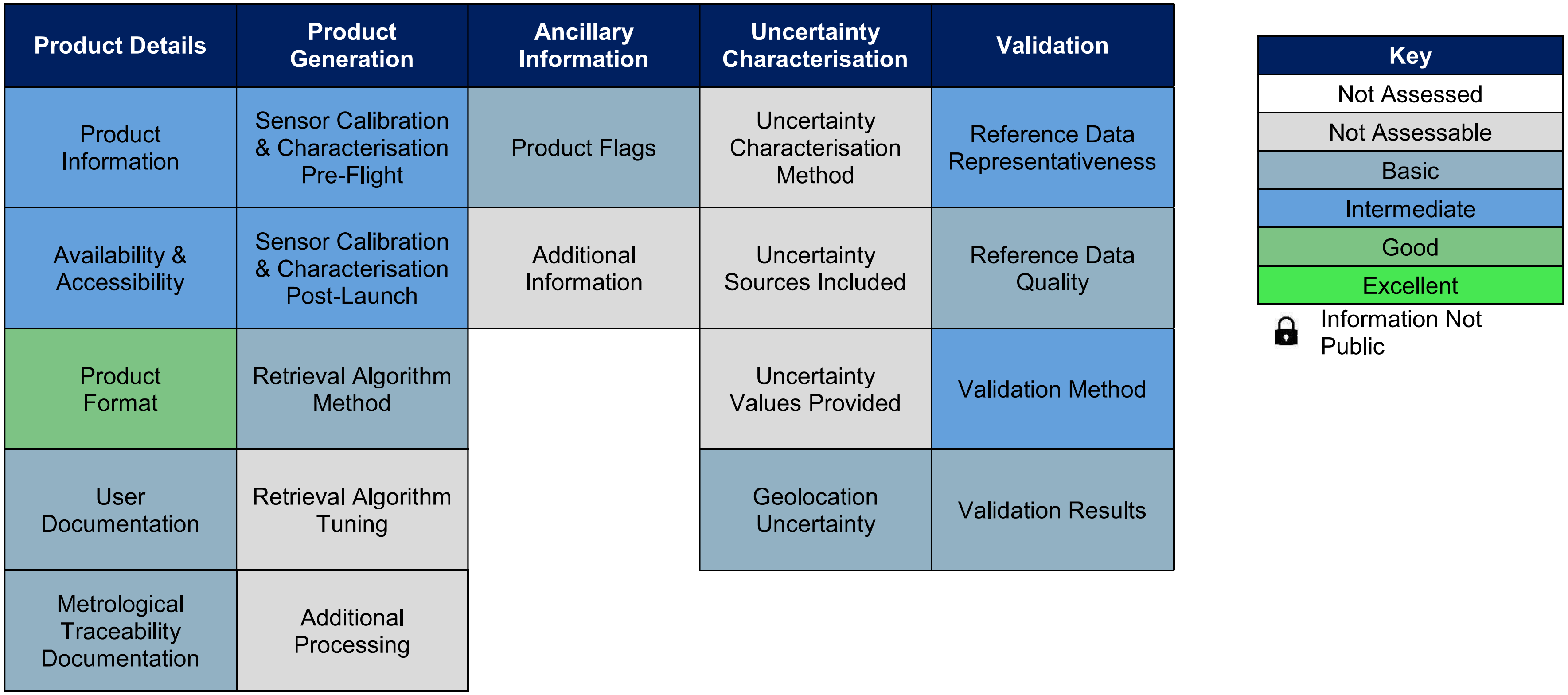


Figure 2-1: OCM-2 Quality Evaluation Matrix

2.2 OCM-2 Detailed Assessment

For this QA period, OCM-2 products were assessed from July to September 2020 with older products included within the plots. The Product Format Consistency Check was repeated for a small number of dates alongside an update of the time-series for the Product Content Check. Also, the Product Coverage check was further investigated as it was noticed that the spatial coverage did not always match what was expected.

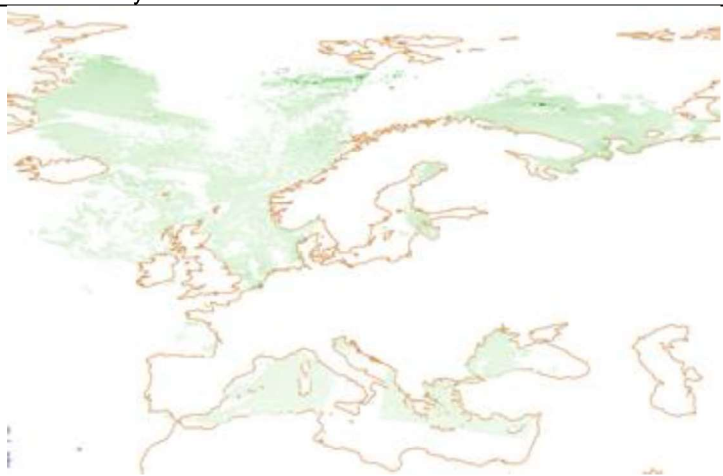
The results are summarised in Table 2-1.

Table 2-1: OCM-2 Q1 2020 QA Summary Results

OCM-2 Product Type	Product Format Consistency Check	Product Content Check	Comment
L1B	Six additional dates analysed, with 78 files for each, and no issues detected – historical analysis is in [RD.2] and [RD.5]	N/A	-
L2B	No issues detected – see above, for scenes being analysed	N/A	-
L2C	No issues detected – see above, for scenes being analysed	No issues detected	Sections 4.2, 4.3 and 4.4 for detailed analysis

3. EDAP QUALITY ASSESSMENT

3.1 Product Details

Product Information	
Product Name	OceanSat-2 OCM2 Level 1 (**L1**) Local Area Coverage (**LAC**) products downlinked then processed on behalf of ESA, by GAF/NSG, to Level 2 (**L2**)
Sensor Name	OCM2
Sensor Type	Optical – Multichannel spectrometer
Product Version Number	Not provided
Product ID	OC2_OPER_OCM2
Processing level of product	L1 B and L2 B & C
Measured Quantity Name	L1: Radiance L2: CL for Chlorophyll-a concentration; DA for Vertical Diffuse attenuation coefficient (Kd) at 490-nm; SE for Total Suspended Matter concentration; AO for Aerosol Optical Depth
Measured Quantity Units	L2 nLw: W cm^{-2} nm^{-1} sr^{-1} L2: CL 0.0 – 60.0 mg m^{-3}; DA 0.01-0.50 m^{-1}; SE 0.0-200 mg L^{-1}; AO 0.0-1.0 unitless
Stated Measurement Quality	Not provided
Spatial Resolution	L1 A & B: 360 by 236 m L2 C: 360 by 360 m
Spatial Coverage	
Temporal Resolution	Daily
Temporal Coverage	October 2015 onwards
Mission coverage	Global
Point of Contact	ESA Helpdesk
Product locator (DOI/URL)	ESA: https://tpm-ds.eo.esa.int/oads/access/collection/OceanSat2 Space Applications Centre, India: https://mosdac.gov.in/data/Missions/oceansat/oscat_home.jsp Global Area Coverage (**GAC**) is available free of charge, while LAC data is available for a fee.
Conditions for access and use	ESA Single Sign-On (**SSO**) account
Limitations on public access	Registration with ESA

Product Abstract	N/A

Product Availability & Accessibility	
Compliant with FAIR principles	ESA archive is available for download after registration
Data Management Plan	Not available to users
Availability Status	Near-Real-Time availability within the ESA archive

Product Format	
Product File Format	HDF
Metadata Conventions	Metadata file provided (filename.meta within product directory) – list of parameters detail in the product specification documents
Analysis Ready Data?	Yes – L2C

Product User Documentation		
Document	*Reference*	*QA4ECV Compliant*
Product User Guide (**PUG**)	• OceanSat-2-Level-1-Product-Specifications, Ver. 1.1, Jun 2010 • OceanSat-2-Level-2-Product-Specifications, Ver. 1.4, Apr. 2017 • PDF on IOCCG website: www.ioccg.org/sensors/OCM-2.pdf	N/A
Algorithm Theoretical Basis Document (**ATBD**)	Not publicly available, but peer-reviewed papers are published, see Section 3.2	N/A

Metrological Traceability Documentation	
Document Reference	Error budget mentioned from Sriperambudur et al. (2015) http://dx.doi.org/10.4236/ojms.2015.54035
Traceability Chain / Uncertainty Tree Diagram Available	Level 1: not provided Level 2: • Normalized water leaving radiance (nLw) < 5% - not provided as a product • CL <30%; DA < 15%; SE < 20%; AO < 20%

3.2 Product Generation

Sensor Calibration & Characterisation – Pre-Flight	
Summary	Sensor characterisation: spatial and radiometric
References	• Pre-launch calibration & Post-launch performance, May 2013 https://iocs.ioccg.org/wp-content/uploads/1450-samir-pal-ocm-2.pdf

Sensor Calibration & Characterisation – Post-Launch	
Summary	Sensor characterisation includes: • On-board calibration using Light-Emitting Diodes (**LEDs**) • Vicarious calibration using an oceanographic buoy • Lunar calibration

	• Spatial and radiometric Image-based characterisation system
References	• Pre-launch calibration & Post-launch performance, May 2013 https://iocs.ioccg.org/wp-content/uploads/1450-samir-pal-ocm-2.pdf • Post-launch calibration of Ocean Colour Monitor 2 using Kavaratti CAL-VAL site observations, Jan 2013 https://www.currentscience.ac.in/Volumes/104/01/0023.pdf • Update of post-launch vicarious, lunar calibrations & current status, June 2015 https://iocs.ioccg.org/2015/files/THU-935-BO9-Chauhan-Calibration.pdf • Cross-calibration of the OceanSat-2 Ocean Colour Monitor (OCM) with Terra and Aqua MODIS, May 2016, https://doi.org/10.1117/12.2224046

Retrieval Algorithm Method ***(Include for Level 2 Products Only)***	
Summary	ATBD is not made publicly available: • Sriperambudur et al. (2015) lists SeaDAS (https://seadas.gsfc.nasa.gov/) as the processor for HDF files • Shanthi et al. (2013) validated the Chlorophyll and TSM products, highlighting that OCM-2 underestimated the high chlorophyll concentration (in-situ) and overestimated the low chlorophyll concentration (in-situ). For TSM, OCM-2 values consistently underestimated the in-situ measurements. • Nagamani et al. (2008) developed an empirical Chlorophyll algorithm for the future launch of OCM-2 based on NASA's NOMAD in-situ datasets
References	• Sriperambudur et al. (2015) http://dx.doi.org/10.4236/ojms.2015.54035 • Shanthi et al. (2013) J. Earth Syst. Sci. 122(2), pp. 479–489 • Nagamani et al. (*2008*) https://ieeexplore.ieee.org/document/4558016

Retrieval Algorithm Tuning ***(Include for Level 2 Products Only)***	
Summary	No relevant documentation has been found.
References	N/A

Additional Processing	
Description	No relevant documentation has been found.
Reference	N/A

3.3 Ancillary Information

Product Flags	
Product Flag Documentation	OceanSat-2-Level-2-Product-Specifications, Ver. 1.4, Apr. 2017
Comprehensiveness of Flags	Section 5.1.8, L2 Flag Data Group – brief description of the L2 product flags

Additional Information	
Ancillary Data Documentation	None provided
Comprehensiveness of Data	N/A
Uncertainty Quantified	N/A

3.4 Uncertainty Characterisation

Uncertainty Characterisation Method	
Summary	No relevant documentation has been found.
Reference	N/A

Uncertainty Sources Included	
Summary	No relevant documentation has been found.
Reference	N/A

Uncertainty Values Provided	
Summary	No relevant documentation has been found.
Reference	N/A
Analysis Ready Data?	N/A

Geolocation Uncertainty	
Summary	The geolocation is visually assessed within Section 4.4.2 where the data is displayed alongside the Natural Earth [RD.6] vector coastline layer at 50 m resolution within QGIS. The two inputs match within the uncertainty of the coastline itself, and there is no indication of systematic errors due to attitude or other errors.
Reference	N/A

3.5 Validation

Validation Activity #1	
Independently Assessed?	Yes – within this report for the derived L2 Chlorophyll-a product
Reference Data Representativeness	
Summary	For this report, we have used data from two AERONET-OC stations and BOUSSOLE with further expansion expected in future iterations. Other, referenced papers have used cruise measurements.
Reference	Section 4.4.2
Reference Data Quality & Suitability	
Summary	The AERONET-OC stations and BOUSSOLE have known origins, while the data quality of the reference data used within the cited peer-reviewed papers is less quantifiable. One scientific paper uses fluorometrically derived Chlorophyll while the other is based on High Performance Liquid Chromatography (**HPLC**).
Reference	Section 4.4.2
Validation Method	
Summary	Follows the marine approach that is defined in [RD.18]
Reference	Section 4.4.2
Validation Results	

Summary	Simple plots at this stage
Reference	Section 4.4.2

4. DETAILED OCM-2 ASSESSMENT

This QA is performed using a sample of OCM-2 L1B (local area coverage radiance products), L2B (local area coverage products as four geophysical parameters: Chlorophyll-a concentration (**clo**), aerosol optical depth (**aod**), total suspended matter (**tsm**) and depth attenuation coefficient (**dac**)) and L2C (local area coverage geo-referenced products as four geophysical parameters) products that have been downloaded for all scenes (i.e. all tracks and frames) applicable to a selection of dates between the 01 January 2017 and 30 September 2020 (dates chosen within this reporting period, based on presence of reduced cloud cover).

4.1 Product Format Consistency Checks

At this stage of the QA process, product format consistency checks are performed on the retrieved OCM-2 products to ensure that, as far as possible, the correct input files were used in the relevant processing stage(s). Also, it was checked that the product format conforms to the format defined in the *EO-SIP Specialisation for OceanSat-2 Mission* document [RD.4].

4.1.1 Product Format Consistency Check Results

For the format consistency check*, since January 2017, a total of 660 OCM-2 (L1B, L2A and L2C) products have been checked; within previous reporting [RD.5] 549 files were reviewed. For both cases, all the files were shown to have used the correct input files and have a valid product format; see Table 4-1 for the number of files checked in the July to August 2020 period.

Table 4-1: OCM-2 EO-SIP Consistency Check.

OCM-2 Product Type	Product SIP Information File	Product Metadata File	Product HDF File**
L1B	78/78	78/78	N/A
L2B	78/78	78/78	N/A
L2C	78/78	78/78	6/6

**The consistency check does not include checking for the existence of a QL/browse image (.png file).*

**The consistency check for *each L2C product includes an additional check of the HDF files found, and their validity, within the (further zipped) product folder.*

4.2 Product Coverage Check

L2C inconsistencies in data coverage were discovered, in particular, (as seen in Figure 4-1) the OCM-2 composite is missing data in the western Mediterranean region for the chosen date. After confirmation of all available L2C data being retrieved from the ESA portal, and composited, an investigation was conducted into the product coverage available on the online portal.

The OCM-2 orbital coverage has at least two orbital configurations, which results in two sets of coverage patterns that alternate daily for each orbital configuration. The first set contains 15 scenes with sections of the western and eastern Mediterranean not having any coverage (as seen in Figure 4-1). The second set has 13 scenes and lacks coverage in the central Mediterranean, southern Italy and the Portuguese Atlantic Ocean (as seen in Figure 4-2). The spatial coverage indicated within the ESA portal can be an overestimate due to the simplification in how the extent is displayed. For example, in Figure 4-1, the Mediterranean scene coverage appears to extend as far as the middle of Crete, but Figure 4-13 shows the cut-off is through Greece and Crete itself is not covered.

Figure 4-1: Image of data coverage lacking data for the eastern and far western Mediterranean.

Figure 4-2: Image of data coverage lacking for the central Mediterranean and Portuguese Atlantic Ocean.

As can be seen in Figure 4-3, after the 03 September 2020 the data coverage swapped to a second configuration that changed from an alternating 14 to 11 scenes per day to between 13 and 15 scenes per day. There are some exceptions where the number of available scenes dropped due to unknown causes. The data coverage for these groups can be seen in Figure 4-4 and Figure 4-5.

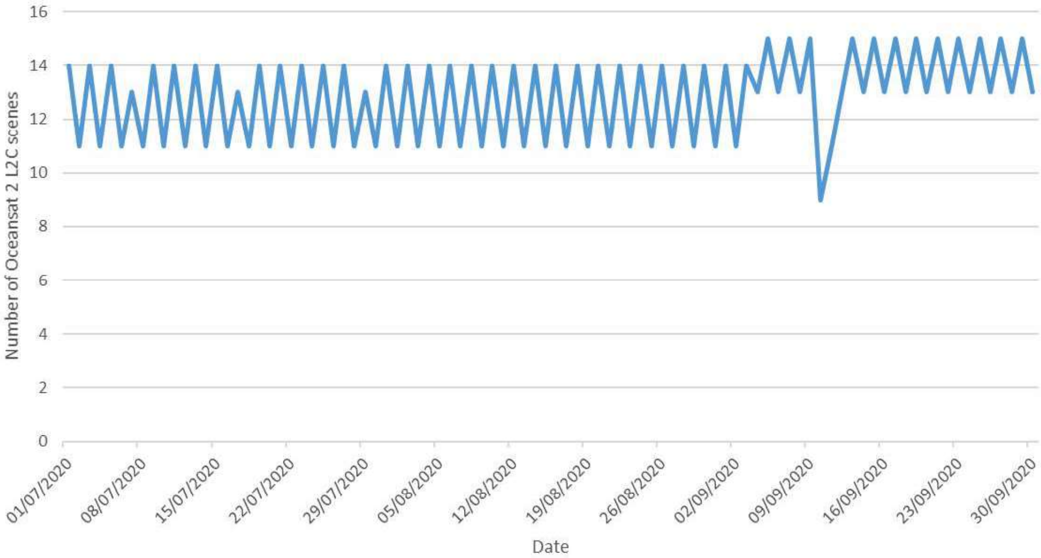


Figure 4-3: Number of OceanSat 2 L2C scenes per day within the ESA Online Dissemination service.

In Figure 4-4, the data coverage is very similar to Figure 4-1 with the main alterations being one extra scene over southern Spain providing more data coverage, one extra scene covering the Black Sea and less scene coverage over the Arctic sea above northern Russia.

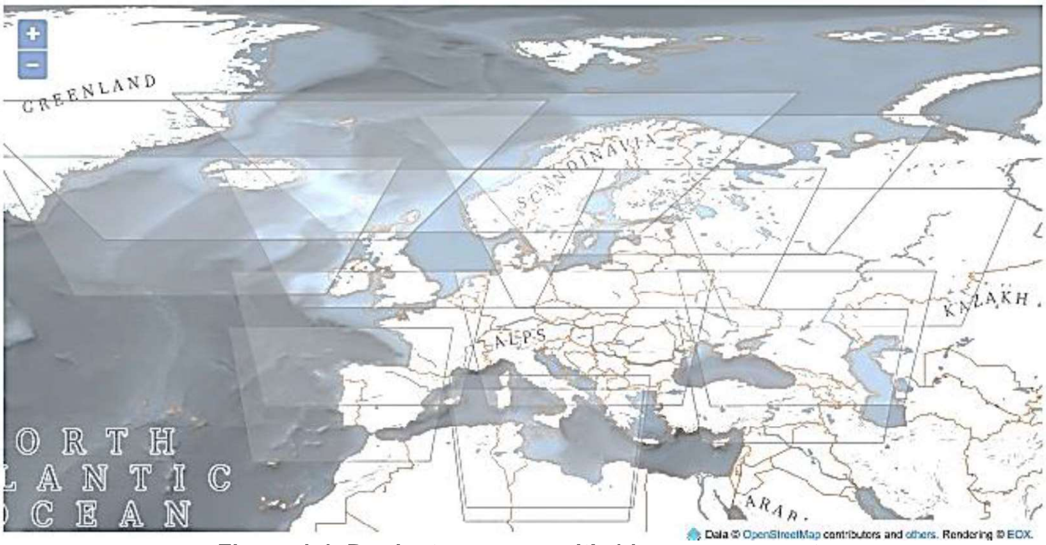


Figure 4-4: Product coverage with 14 scenes present.

In Figure 4-5, the scene coverage is very similar to Figure 4-2 with the main differences in scene coverage being in the Arctic sea above Russia, Sweden, Norway and Finland alongside a slight scene adjustment in coverage over north-western Spain.

Figure 4-5: Product coverage with 11 scenes present.

For 2020, several dates were found not to have all of the expected L2C files for unknown reasons, which is shown in Table 4-2.

Table 4-2: Table of known dates for 2020 which are lacking files dues to unknown reasons.

Date	Number of missing scenes	Date	Number of missing scenes
03/01/20	1	**30/05/20**	1
07/02/20	6	**01/06/20**	3
12/02/20	6	**12/06/20**	4
11/03/20	1	**07/07/20**	1
18/03/20	1	**17/07/20**	1
11/04/20	1	**29/07/20**	1
22/04/20	3	**10/09/20**	4
28/05/20	6	**11/09/20**	4

4.2.1 Yearly analysis of L2C file availability

Building upon the results shown in Figure 4-3, a year-on-year analysis of file availability for L2C files was conducted ranging from October 2015 to September 2020. The file availability was measured by assessing the number of downloadable L2C files per day from the ESA Online Dissemination service. The number of the files available per day over yearly periods were plotted and are shown in Figure 4-6 to Figure 4-10.

As can be seen in Figure 4-6, the number of available L2C files initially available in 2015 was subject to a great degree of variability. This pattern is speculated to be due to an initial set up period in terms of handling the integration of L2C data into the ESA Online

Dissemination service. As the data proceeds into 2016, a more consistent pattern starts to emerge oscillating between 12 and 13 files per day, leading to 13 and 15 files per day. This change is likely to be influenced by the establishment of a stable orbital pattern allowing for consistent capturing of data; furthermore, a different oscillation pattern can be seen in April 2016 and could be caused by an orbital manoeuvre or issues with downlinking. However, as seen in Figure 4-1 and Figure 4-2, this can affect the actual data coverage available for specific areas in Europe. Several deviations can be seen where there are either sharp dips or peaks in the available number of files as can be seen near the 27 May 2016 in Figure 4-6. The causes of these individual deviations are not known.

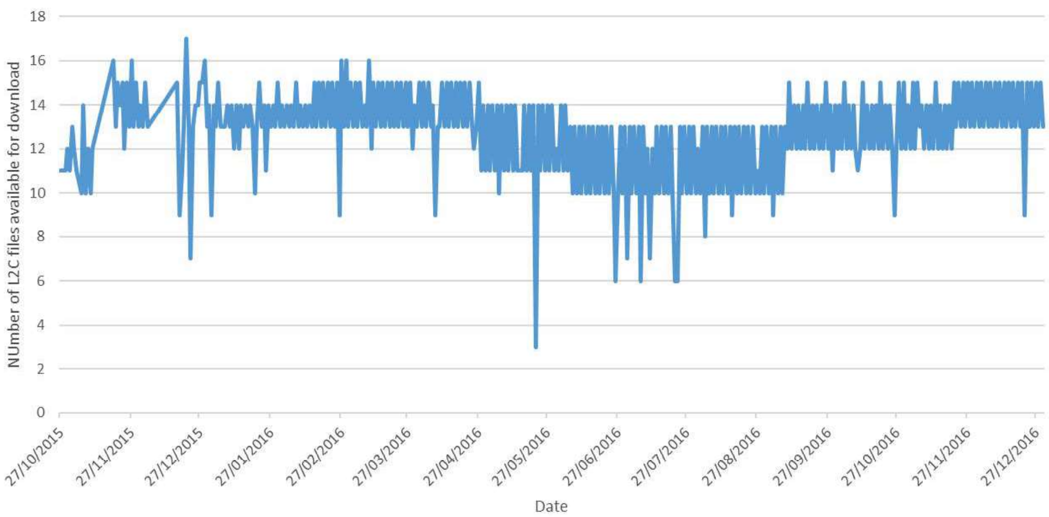


Figure 4-6: Number of L2C files for October 2015 to December 2016.

For Figure 4-7 and Figure 4-8, a very similar consistent orbital pattern can be seen as shown by the changes in the oscillation pattern of the available data. Deviations in the available number of files can be seen however of note is the change between the first and second orbital pattern change where a massive drop in the available number of files for a single day can be seen near the 01 May 2018. This drop could be influenced by orbital corrections applied near or on this day or an issue with downlinking.

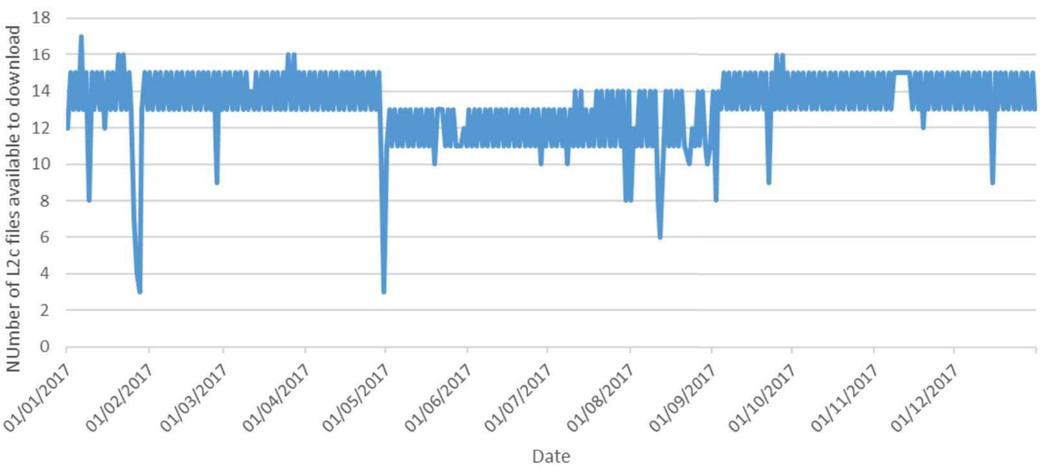


Figure 4-7: Number of L2C files availability for 2017.

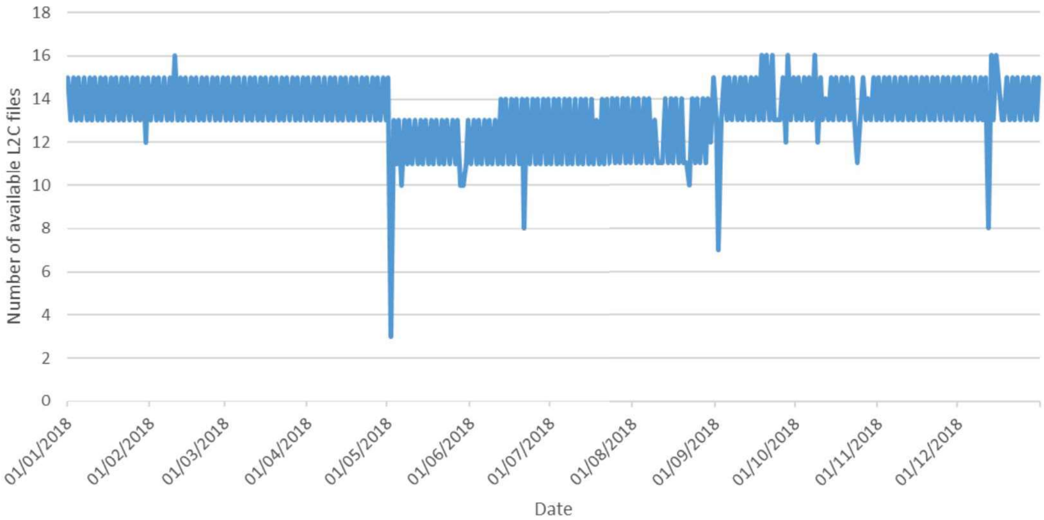


Figure 4-8: L2C file availability for 2018.

In Figure 4-9, a stable orbital pattern across the whole year can be seen with two shifts in the oscillation pattern seen clearly. Between the 01 May and 01 September in 2017 and 201, there are two different oscillation patterns ranging from 11 to 13 and 11 and 14. The duration of the oscillation pattern of 11 to 13 files per day appears to shorten going from 2017 to 2018. For 2019, this oscillation pattern has ceased with only a pattern of 11 to 14 files being present, which suggests that the improvement to the data coverage seen in this period for 2017 and 2018 was fully implemented going forward.

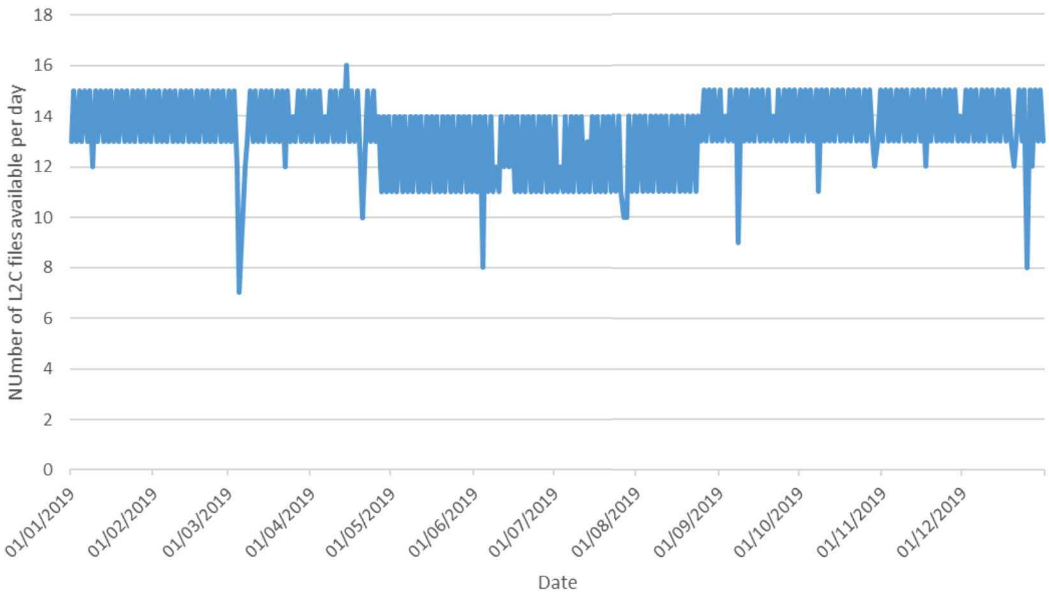


Figure 4-9: L2C file availability for 2019.

As can be seen in Figure 4-10, the orbital patterns remain consistent from 2019, showing no significant changes to data coverage were needed during this period. Of note, the period where the data coverage oscillation pattern covered 11 to 14 files per day appears to have been shortened by a few weeks starting later in May 2020 compared to early May in 2019. Individual deviations to the available number of files can be seen, but the causes of these deviations are again unknown.

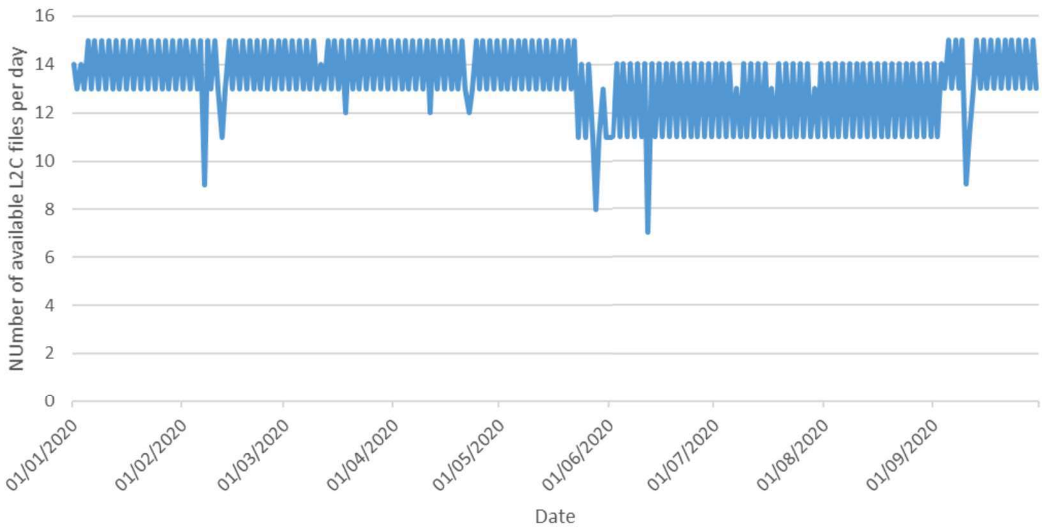


Figure 4-10: L2C file availability for January 2020 to September 2020.

The initial file availability varied significantly, from when data was first uploaded in 2015 going through to early 2016. This variation is assumed to be caused by technical issues with downlinking/making the data available to the ESA service. The two stable orbital patterns, from 2019 onwards, appear to be one pattern consisting of 13 to 15 files per day lasting roughly eight months from September to May and four months of 13 to 15 files per day. This pattern leads to consistent data coverage patterns which, whilst they still have spatial blind spots as seen in Figure 4-1, allows for a consistent timeline of spatial coverage to be extrapolated barring large scale orbital corrections or adjustments being applied.

Furthermore, as can be seen in Figure 4-11, orbital patterns were assessed to estimate the exact number of files that should be present for a given day. This assessment was then compared in terms of the actual number of files available for a given day and the number of days not containing the expected number of files; expectation based on the orbital configuration over the three-month periods from October 2015 to July 2020.

The results from Figure 4-11 show that during the initial 3-month periods (October 2015 to July 2016) 15% to 52% of the days showed missing data. This 9-month period represents the highest frequency of data loss, most likely influenced by issues with downlinking/ integration of this data stream into the ESA Online Dissemination service. Over time, however, the number of days with file inconsistencies dropped significantly with 2016-2017 reporting 6% to 15% of days showing mismatch. Finally, 2019 onwards showed that no more than 9% of data were missing for any three months. Overall, this indicates that data availability and coverage have drastically improved since the initial integration of OceanSat-2 NRT data to the ESA Online Dissemination service.

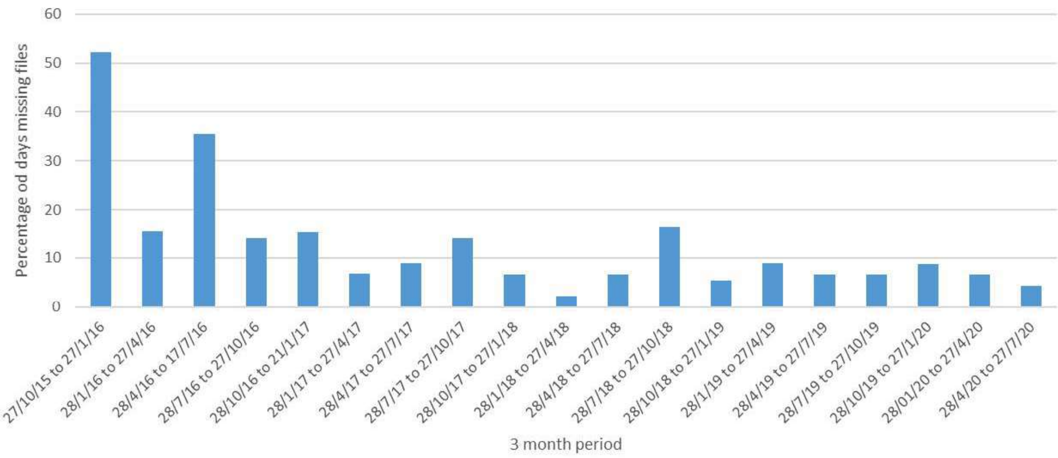


Figure 4-11: Percentage of days, per 3-month period from October 2015 to July 2020, having an inconsistent number of L2C files contrary to what is expected from the orbital pattern.

4.3 Product Content Checks

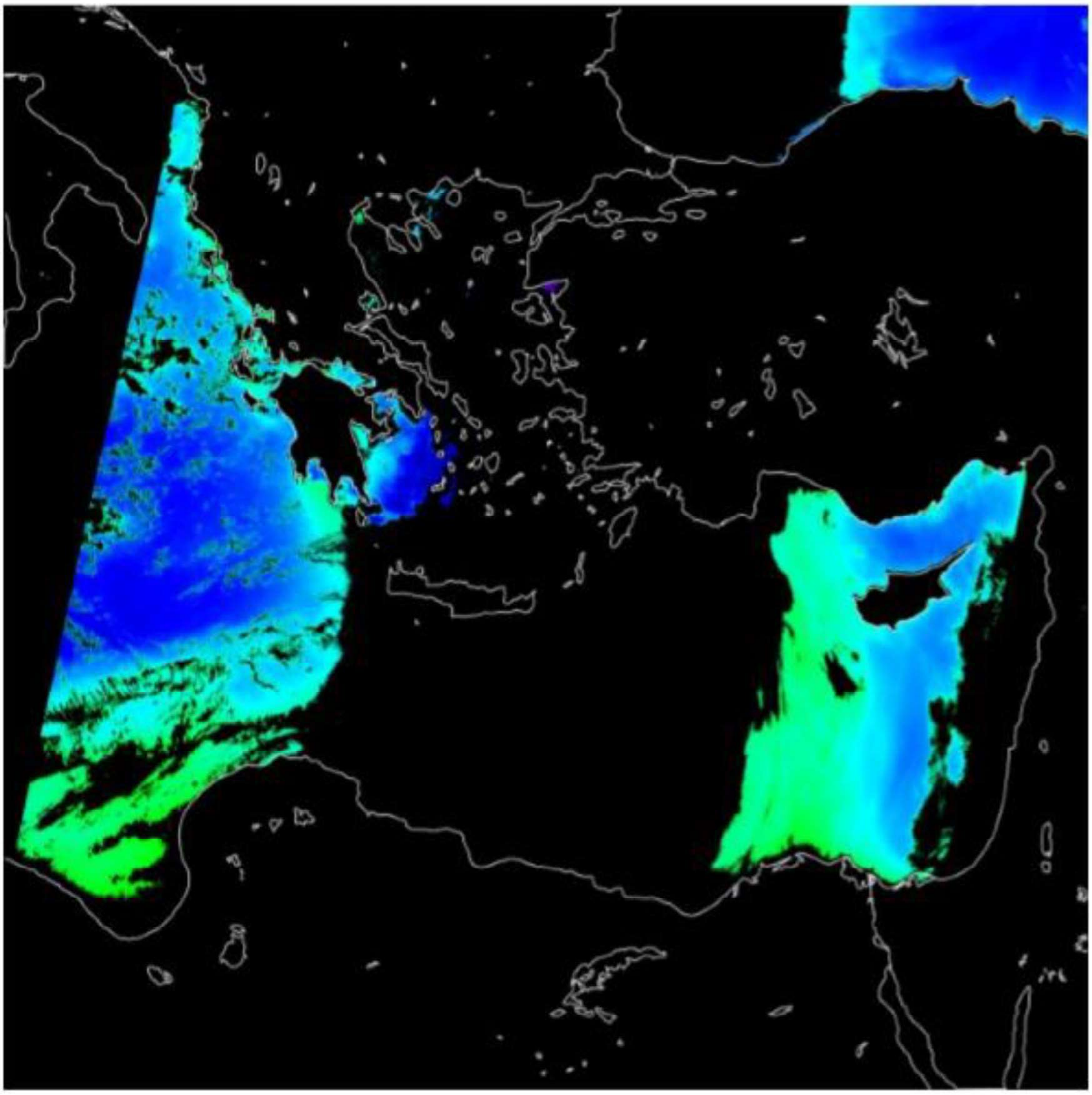
At this stage of the QA process, product content checks are performed. These checks use both the QuickLooks (**QLs**) and GeoTIFFs within the retrieved OCM-2 L2C products to visually assess product content (i.e. radiance and geophysical data) in terms of consistency and quality.

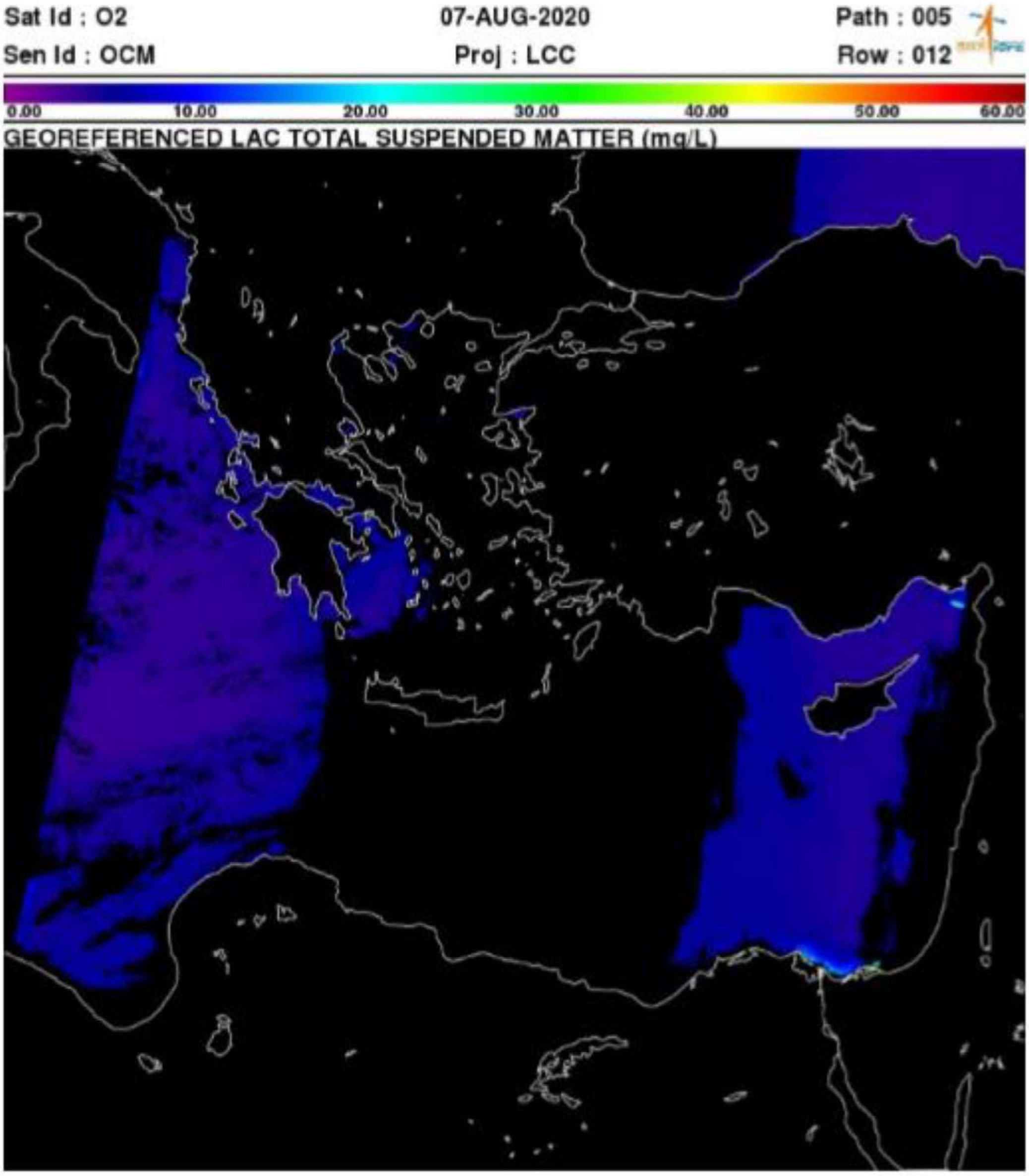
4.3.1 Product Content Check Results

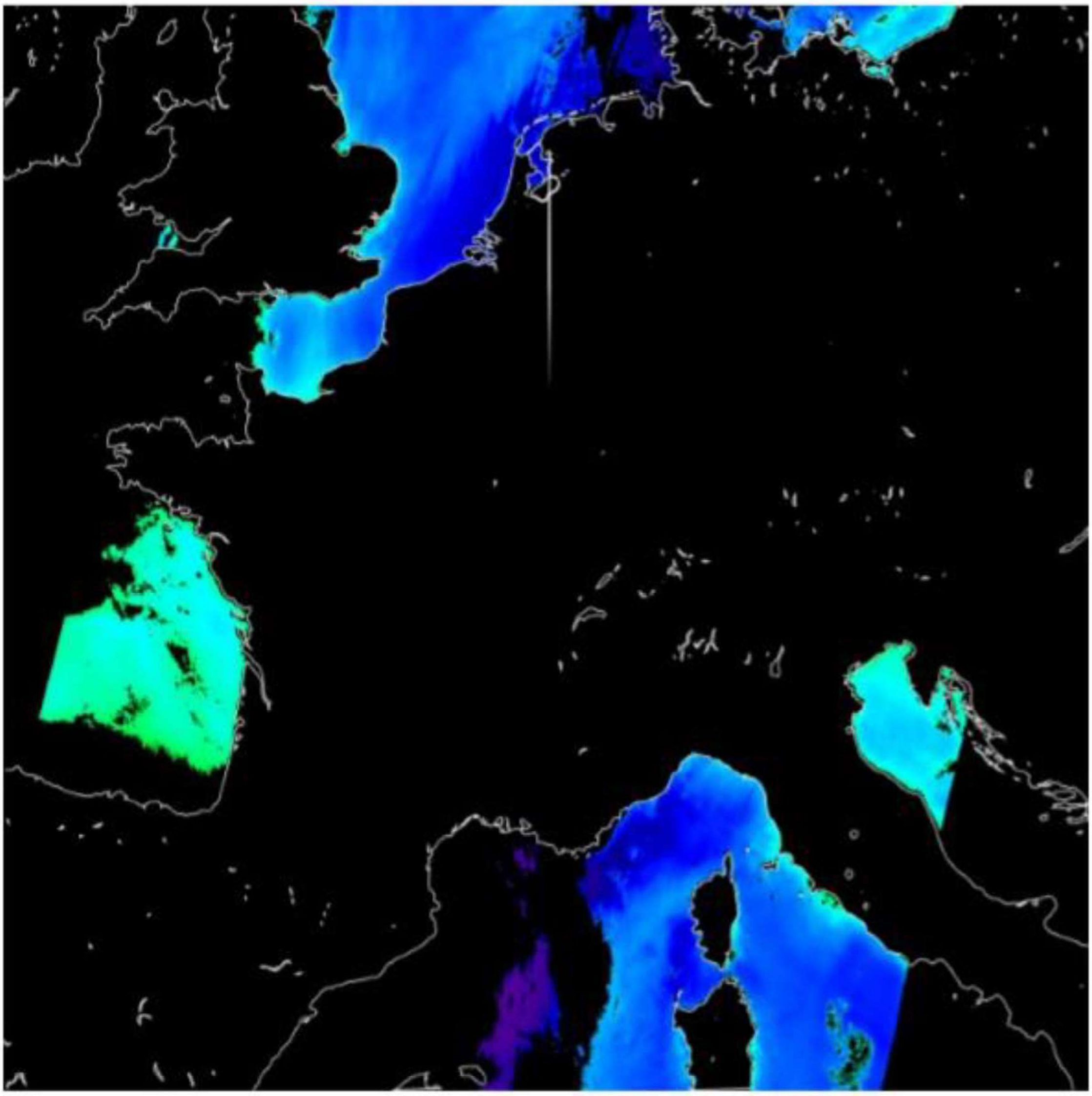
A selection of QLs, associated with the OCM-2 L2C products, retrieved for this reporting period, are shown in Figure 4-12 (images shown over several pages). It is important to note that the Chlorophyll-a concentration values provided in these OCM-2 QLs are restricted by a pre-specified range (i.e. $0 \leq clo \leq 5$ mg.m^{-3}) and not the actual range. Therefore, consistency and quality assessments on Chlorophyll-a concentration values cannot be accurately performed using the QLs alone.

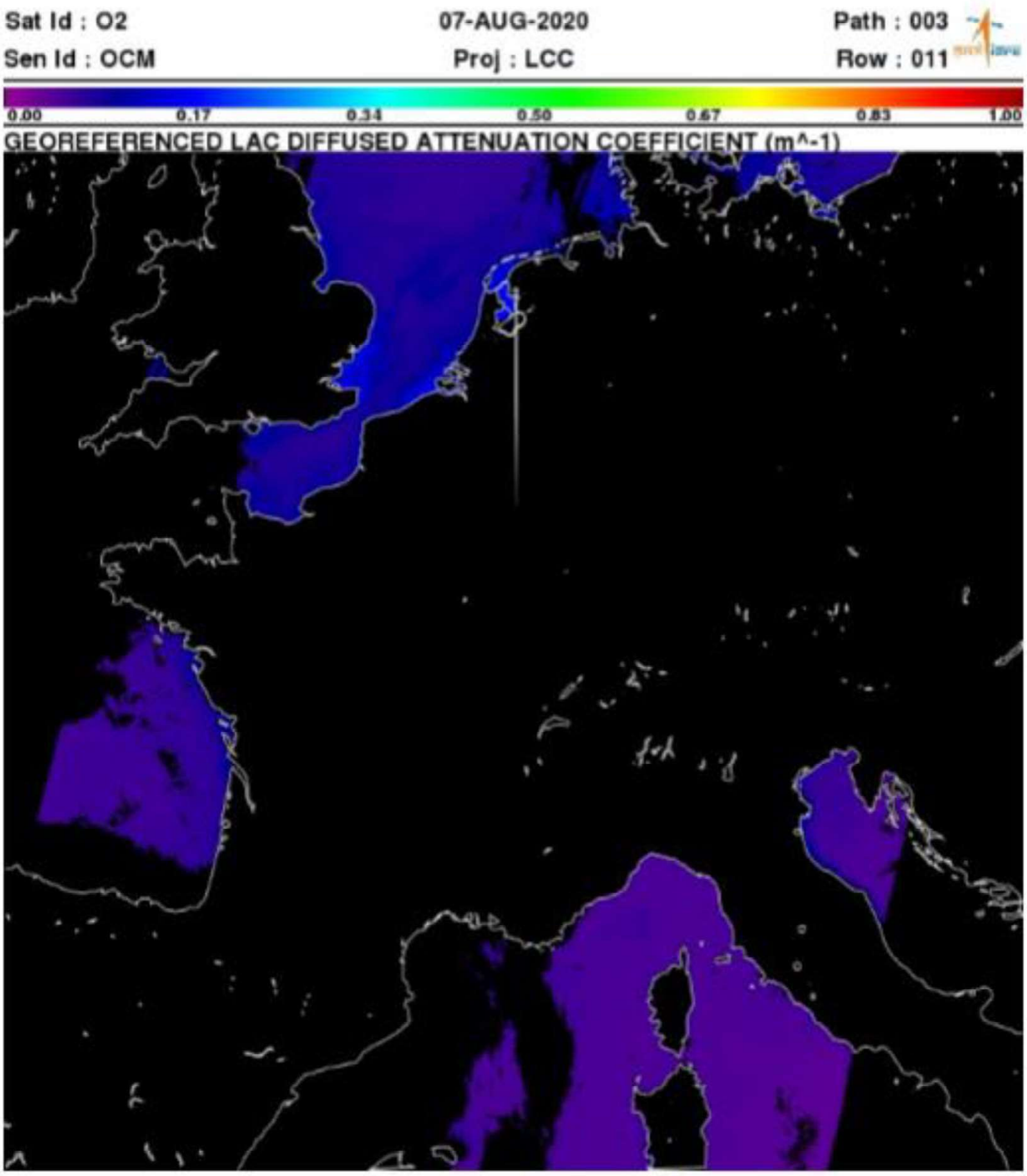
The Chlorophyll-a concentration consistency and quality assessments are best performed using the Chlorophyll-a concentration composite generated for this assessment (shown in Figure 4-13), which does not enforce a pre-specified range. It also includes the Natural Earth [RD.6] vector coastline layer at 50 m resolution, which allows geometric accuracy to be assessed visually. Overall, the OCM-2 composites are comparable to the estimations derived from the ocean colour products produced by NASA's MODIS-Aqua and Suomi-NPP VIIRS sensors (see Figure 4-14). The high concentrations in the southern North Sea and German Bight are related to suspended sediment, which is visible in the VIIRS pseudo-true colour composite as lighter coloured water.

Note: In previously analysed imagery, as expected, poor Chlorophyll-a concentration estimations are seen to dominate high latitude regions where the high solar zenith angles primarily impact radiance retrievals. Also, those regions that have dense cloud cover, coastlines and turbid coastal waters; as expected when using an 'open ocean' band ratio algorithm, e.g. [RD.7].




Sat Id : O2
Sen Id : OCM
07-AUG-2020
Proj : LCC
Path : 005
Row : 012
0.00
10.00
20.00
30.00
40.00
50.00
60.00
GEOREFERENCED LAC TOTAL SUSPENDED MATTER (mg/L)




Sat Id : O2
07-AUG-2020
Path : 003
Sen Id : OCM
Proj : LCC
Row : 011
0.00
0.17
0.34
0.50
0.67
0.83
1.00
GEOREFERENCED LAC DIFFUSED ATTENUATION COEFFICIENT (m^-1)

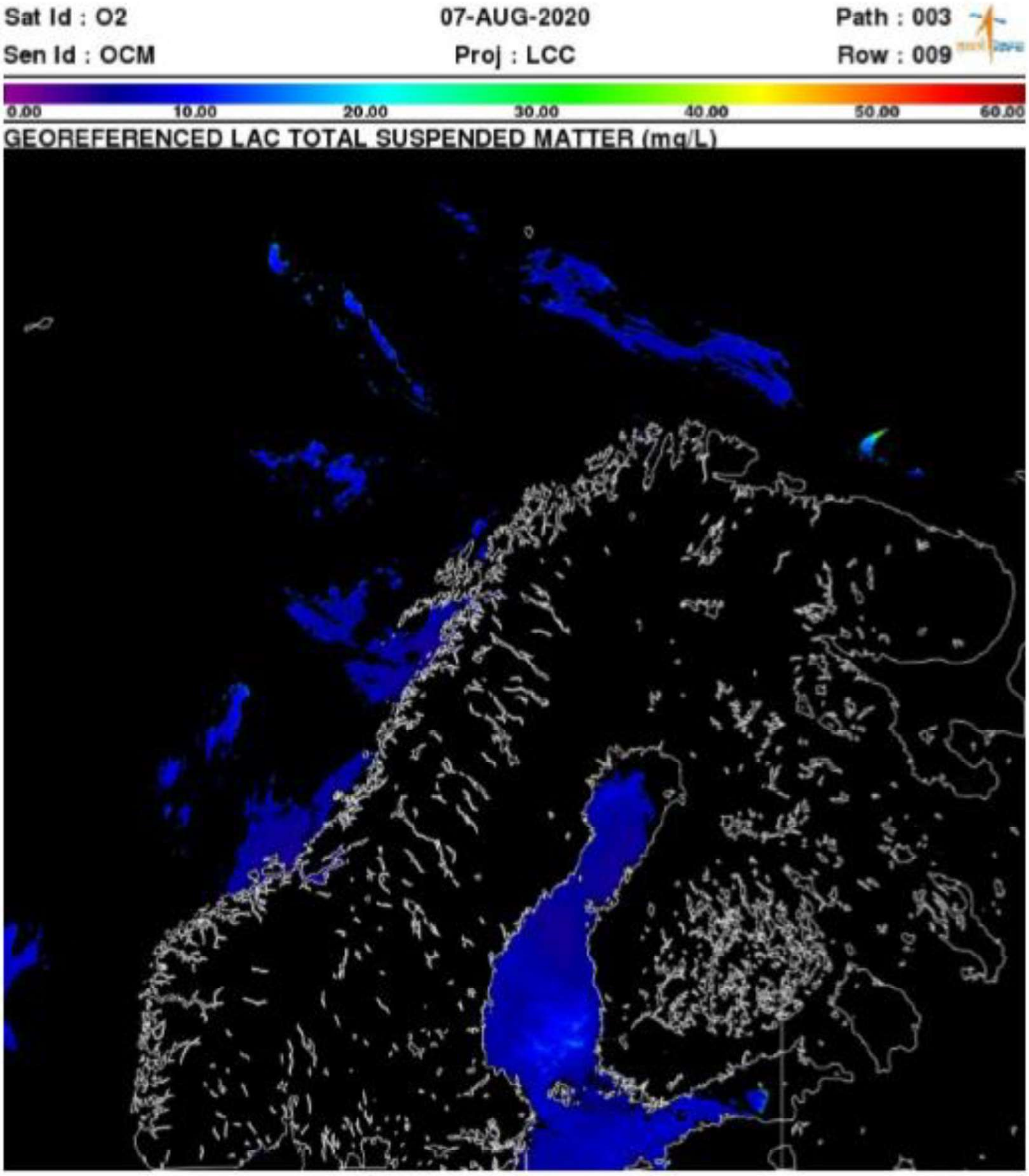


Figure 4-12: Sample of OCM-2 QLs for the 7 August 2020.

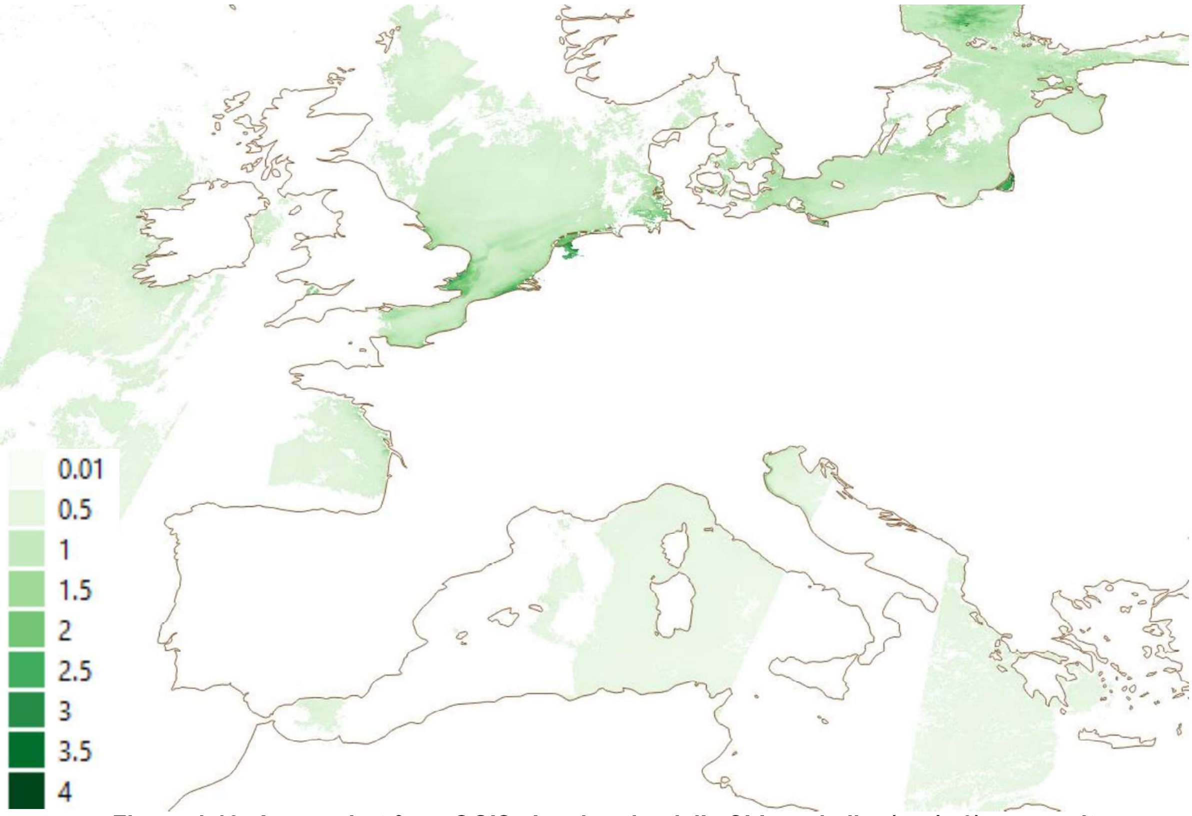


Figure 4-13: A snapshot from QGIS showing the daily Chlorophyll-a (mg/m3) composite using data from 7 August 2020.

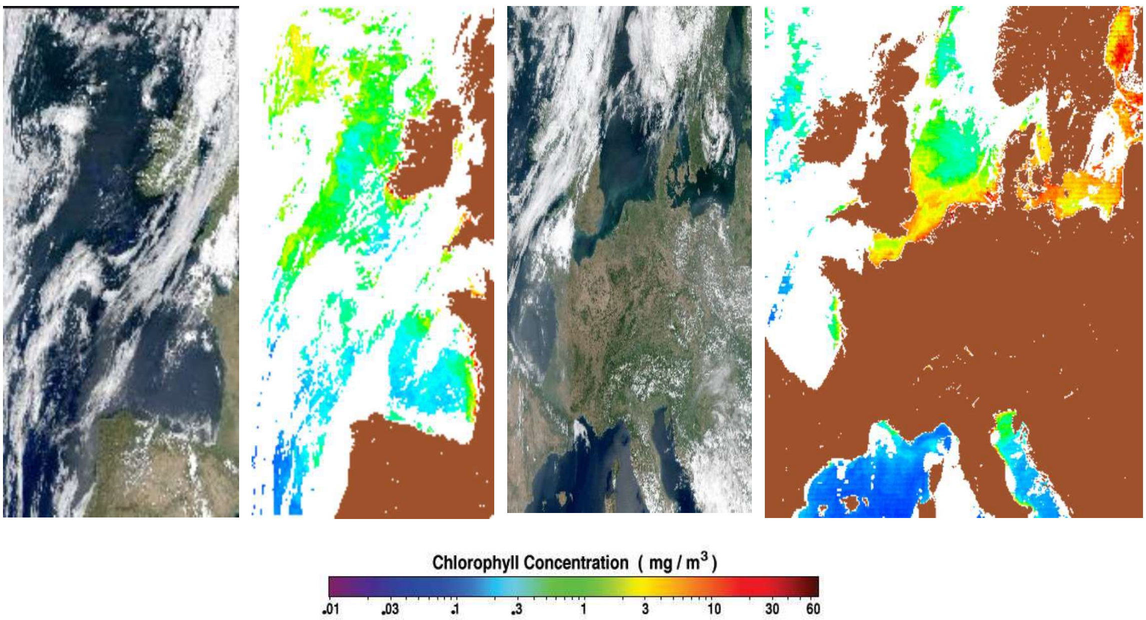


Figure 4-14: MODIS-Aqua and Suomi-NPP VIIRS Chlorophyll-a products from the 7 August 2020 (left to right, respectively) over Central Europe as the pseudo-true colour composite and then chlorophyll product.

4.4 Product Quality Assessment

4.4.1 DIMITRI Sensor to Sensor Assessment

The Top of Atmosphere (**TOA**) comparison is performed using the Database for Imaging Multi-spectral Instruments and Tools for Radiometric Intercomparison (**DIMITRI**) software [RD.8]. The software was received from ARGANS and updated to a newer version of IDL with OceanSat-2 data ingestion and processing included. The integration activities are described in an internal report [RD.9].

The sensor recalibration approach was initially tested by downloading OCM-2 L1B, Moderate Resolution Imaging Spectroradiometer (**MODIS**)-Aqua L1B granules (MYD021KM), and Sentinel-3 A&B OLCI L1B data over the BOUSSOLE data buoy from August to October 2019; see Table 4-3. The total number of scenes across all instruments was 323.

Table 4-3: Ingested scenes/granules available for each month.

Months	OceanSat-2 OCM-2 L1B	Sentinel-3A OLCI L1B	Sentinel-3B OLCI L1B	MODIS-Aqua L1B (granules)
August 2019	15	22	22	51
September 2019	15	20	20	52
October 2019	12	30	26	38
Total	**42**	**72**	**68**	**141**

A Sensor-to-Sensor Comparison (called 'Sensor Recal' in DIMITRI) was run with each of the three non OceanSat missions as the reference sensor and OceanSat-2 as the target sensor.

By increasing the Angular Matching Criteria (**AMC**) from 10 to 30 for the three angles (Sensor Zenith Angle (**SZA**), Viewing Zenith Angle (**VZA**) and Relative Azimuth Angle (**RAA**)), the AMC increased to 45. This relaxation of the criteria was sufficient data to generate results for MODIS-Aqua but not the other two ocean colour missions. When the overpass times (mean local solar time) for the ocean colour missions was reviewed, it was clear that MODIS-Aqua had the closest overpass time:

- Sentinel-3A: 10:00
- MODIS-Terra: 10:30
- OceanSat-2: 12:00
- MODIS-Aqua: 13:30
- Sentinel-3B: Depends on mission phase

Therefore, for the rest of 2019 and 2020 (up to October) only OceanSat-2 and MODIS-Aqua data were downloaded. Unlike the MODIS instruments that orbit at 705 km, OceanSat-2 orbits at 720 km and, due to its smaller swath (1440 km) compared to MODIS (2330 km), it does not necessarily view every part of the earth every two days [RD.10].

The OceanSat-2 data was only downloaded if it visually looked cloud-free in the ESA Online Dissemination service and then matching dates were downloaded for the MODIS-Aqua data, to reduce the number of files to download. By including these additional scenes, the number of L1B data points held in the DIMITRI database increased from 323 to 557.

With this larger dataset, it was possible to run the Sensor Recal without increasing the AMC. The OceanSat-2 data has been manually cloud flagged while MODIS has the cloud cover assessed both automatically and manually. Figure 4-15 shows the plot of the OceanSat-2 versus MODIS-Aqua doublet observations for four of the five coincident wavelengths – the other is 412 nm that also shows OceanSat-2 is higher than MODIS-Aqua.

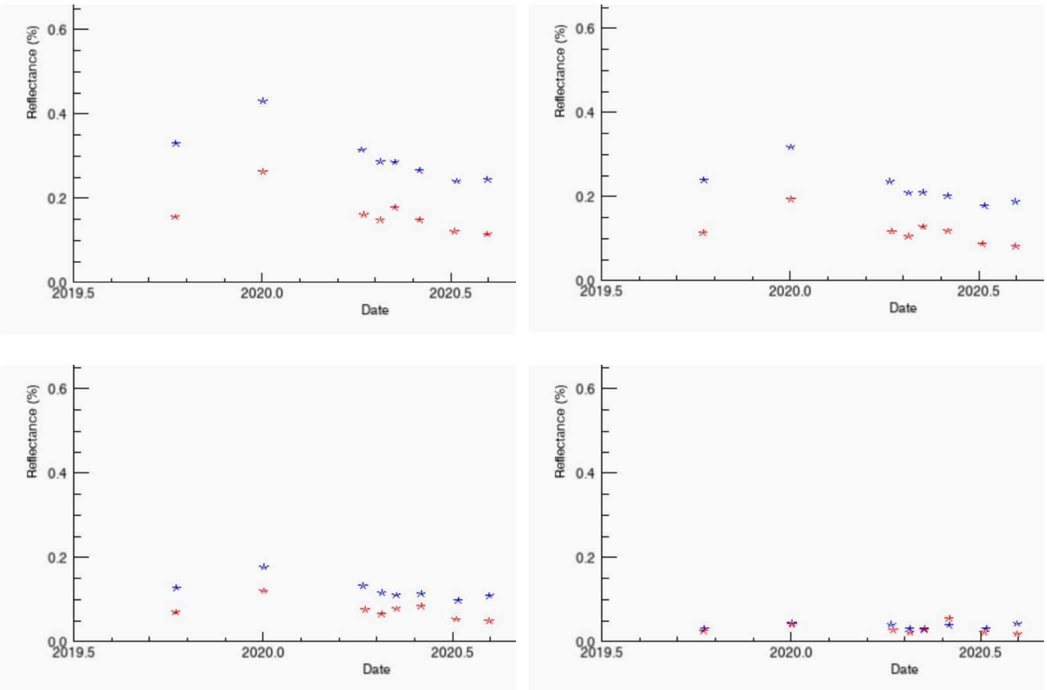


Figure 4-15: DIMITRI OceanSat-2 (blue) versus MODIS-Aqua doublet (red) observations for 443 (top left), 490 (top right), 555 (bottom left), 750 (bottom right) nm wavebands.

Plotting the estimation of the bias for 490 and 750 nm further shows the difference, which is almost flat over the time period in the visible but shows an increase over time in the near-infrared; see Figure 4-16.

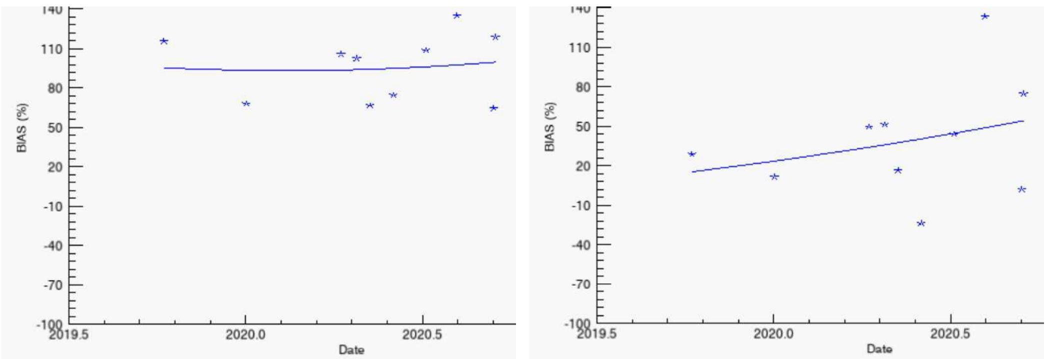


Figure 4-16: DIMITRI bias plot for OceanSat-2 compared to MODIS-Aqua for the 490 (left) and 750 (right) nm wavebands.

Previous results, over Libya-4 [RD.10], indicated that the 412 nm band difference between OceanSat-2 and MODIS-Aqua was between 5-20% and for 443 nm it was between 5-10%. These differences are much smaller than these preliminary results. It was noticed in the OceanSat-2 imagery that there was sunglint, see Figure 4-17, and so this could be having an effect on the results. There are also only a low number of matching points and the code updates will be further checked for issues. So, the preliminary conclusion is that further analysis will be needed.

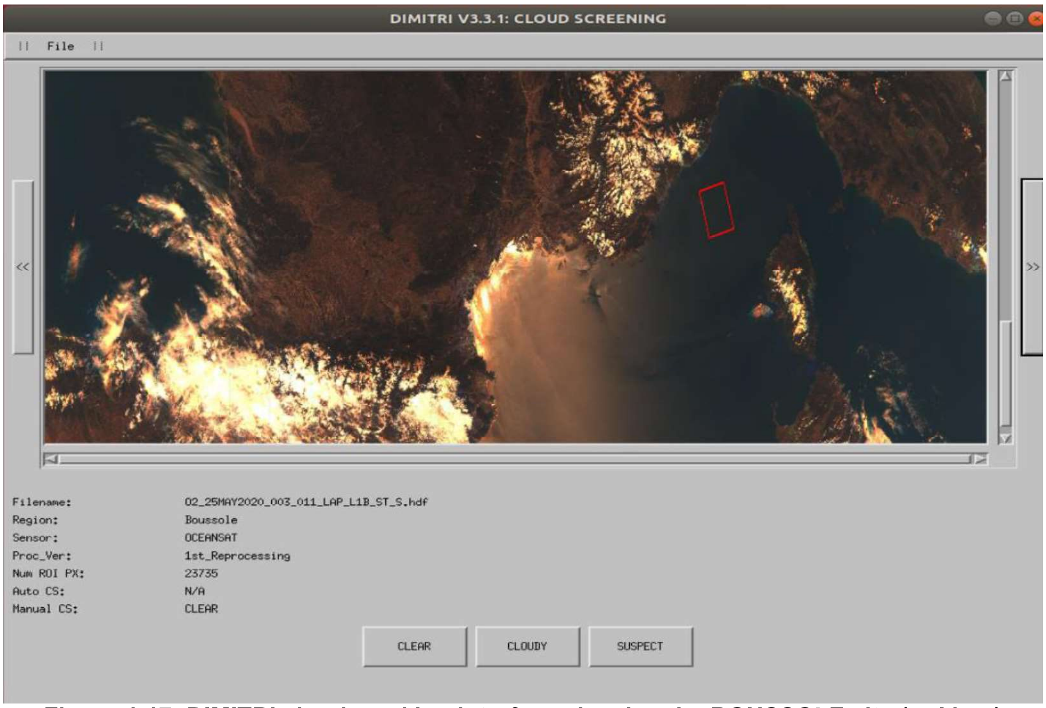


Figure 4-17: DIMITRI cloud masking interface showing the BOUSSOLE site (red box) overlaid on the OceanSat-2 Quicklook.

4.4.2 Level 2 Product Validation

A Python script was developed to produce product quality statistics for inclusion in these quarterly OCM-2 QA reports. In this report, the time-series has been expanded to include July 2020 onwards. As described by [RD.11], the AERONET-OC network consists of globally distributed autonomous radiometer systems maintained at fixed offshore sites.

The script extracts a point of interest from a set of supplied L2C OCM-2 products, with the plot showing time-series values that correspond to the mean and standard deviation of the point of interest specified (a kernel that is three by three pixels in size and is centred on the supplied latitude/longitude).

For Figure 4-18, 298 products were analysed for the period from 03 January 2017 to 30 September 2020 (within this report, 33 new products added from the start of July to the end of September 2020); the values shown correspond to the location of the AERONET-OC Acqua Alta Oceanographic Tower. The OCM-2 Chlorophyll-a (clo) concentration and Aerosol Optical Depth (aod) for each chosen date (that appeared cloud-free from a visual inspection of the QLs) have been plotted. Also, the plot shows AERONET-OC (*in-situ* sensor) estimated Chlorophyll-a values; provided as part of the AERONET-OC dataset.

Additional plots have also been produced for Gustav Dalen (Figure 4-19) and BOUSSOLE (Figure 4-20). BOUSSOLE uses the same path and row as the Acqua Alta Oceanographic Tower, while Gustav Dalen uses Path 4 Row 10. From 2017 to 2020, 227 products were analysed to overlap with available AERONET-OC data, with the Gustav Dalen AERONET-OC instrument operating during the summer months (May to September); for this report, another 29 dates were considered for 2020.

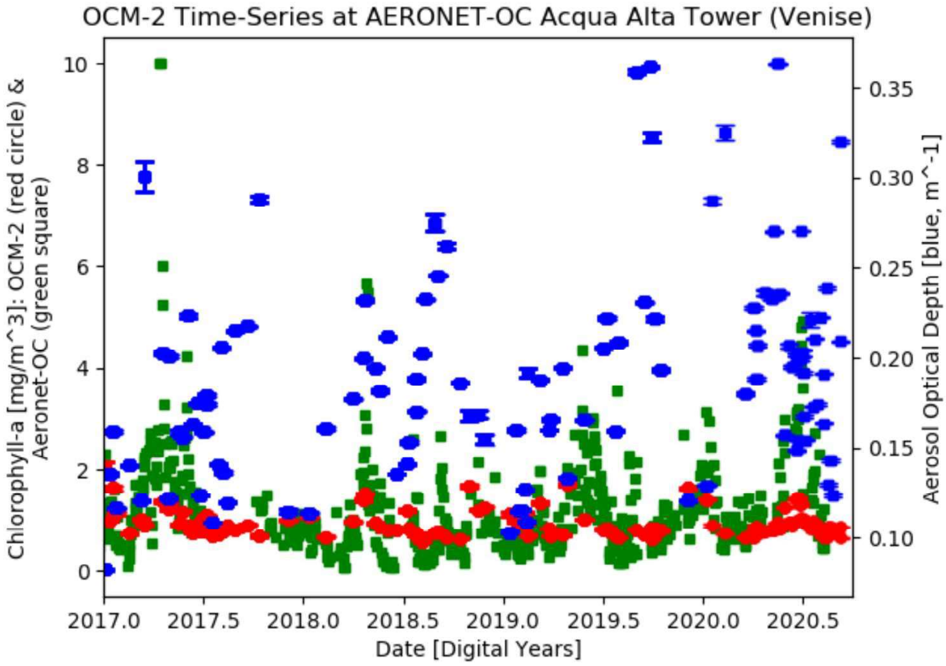


Figure 4-18: Time-series plot of the OCM-2 Chlorophyll-a (clo) and Aerosol Optical Depth (aod) products extracted from the Level 2C files, and AERONET-OC estimated Chlorophyll-a for the location of the AERONET-OC Acqua Alta Oceanographic Tower; data courtesy of AERONET website[1]/Giuseppe Zibordi.

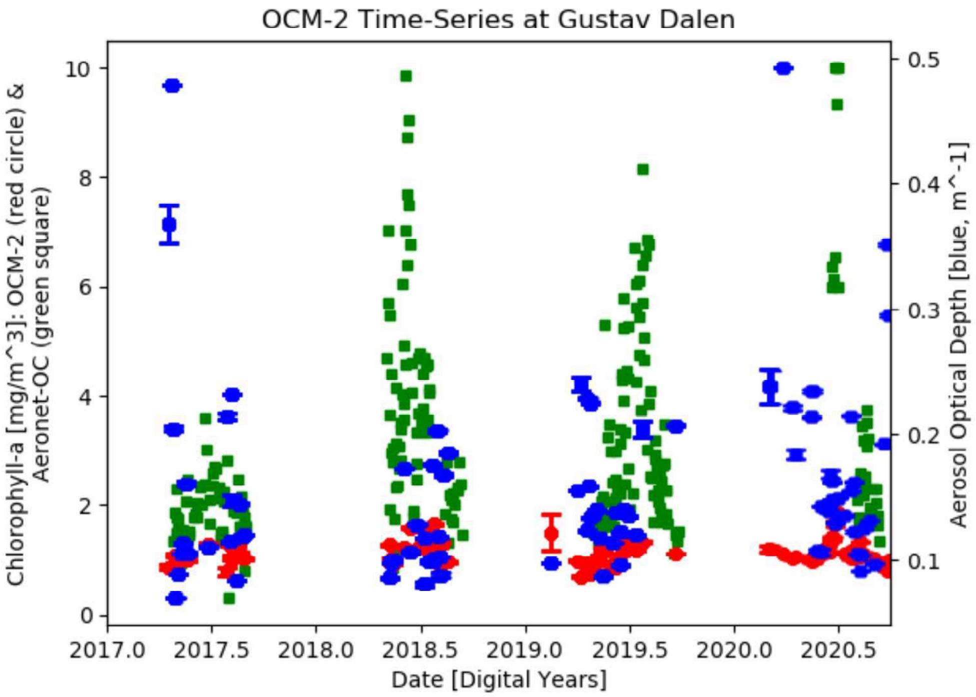


Figure 4-19: Time-series plot of the OCM-2 Chlorophyll-a (and Aerosol Optical Depth from the Level 2C files and AERONET-OC estimated Chlorophyll-a for the Gustav Dalen Tower; data courtesy of AERONET website/Giuseppe Zibordi.

[1] https://aeronet.gsfc.nasa.gov/cgi-bin/type_one_station_seaprism_new?site=Venise&nachal=0&year=25&aero_water=0&level=1&if_day=0&if_err=0&year_or_month=1

BOUSSOLE is a data buoy rather than AERONET-OC station, and so the in-situ data has been acquired differently; currently, the surface sampling (fluorometrically and HPLC derived Chlorophyll) is being plotted; surface sampling data only available up until January 2018.

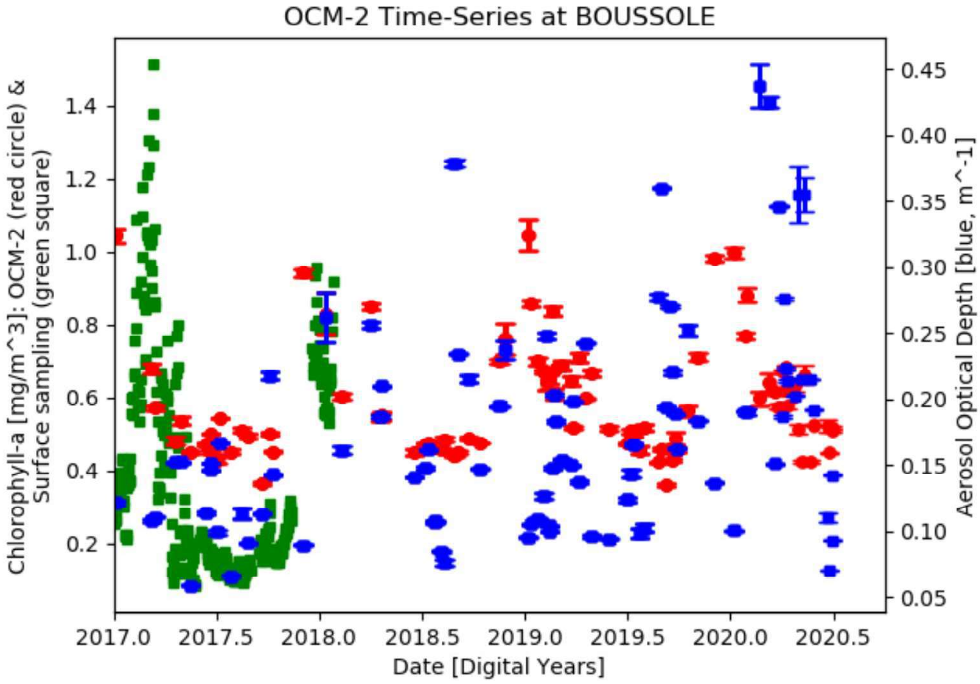


Figure 4-20: Time-series plot of the OCM-2 Chlorophyll-a and Aerosol Optical Depth from the Level 2C files, and surface sampling Chlorophyll-a for BOUSSOLE; data courtesy of BOUSSOLE website[2].

There are several sources of uncertainty, e.g. the AERONET-OC bands are not the same are the OCM-2 bands. However, overall, the plots for both the Acqua Alta Oceanographic Tower and Gustav Dalen show that the AERONET-OC estimated Chlorophyll-a concentrations are significantly higher than the OCM-2 estimates, which could mean that the OCM-2 output is underrepresenting the natural phytoplankton variability.

4.5 Conclusions

The conclusions from this quarterly Quality Assessment report for OceanSat-2 OCM (for Q3 2020) are:

- **No specific issues have been detected for the L1B or L2B products**. At this stage, they have been checked in terms of product format consistency rather than scientific data quality. However, it is acknowledged the L1 quality will have an impact on the L2 analysis and so needs to be analysed going forward.
- It has been noticed that occasionally **scenes are missing when they would be expected to be present** in ESA's Online Dissemination service. Overall, it was determined that several orbital configurations were available with an oscillating pattern that provided consistent levels of data coverage depending on what

[2] http://www.obs-vlfr.fr/Boussole/html/boussole_data/other_useful_files.php

configuration was present. However, during the initial 3-month periods of data availability in the service, the frequency of data deviation was high.

- **L1B: DIMITRI analysis over BOUSSOLE shows that the OceanSat-2 TOA reflectance data is higher than the MODIS-Aqua data.** The DIMITRI analysis focused on comparing OceanSat-2 to MODIS-Aqua as their overpass times are similar, so doublets were extractable. Data from August 2019 to October 2020 was analysed, and sufficient doublet matchups were found, but they remain limited and so the results should be viewed with caution.

- **L2C: No Issues have been detected with the product format consistency with minor issues discovered for the product content**:
  - From the Q1 report [RD.12], poor Chlorophyll-a concentration estimations are seen to dominate high latitude regions where radiance retrievals are primarily impacted by high solar zenith angles not correctly accounted for within the atmospheric correction; acknowledged as an issue within version 1.4 of the L2 Product Spec [RD.13].
  - Inaccurately estimated OCM-2 Chlorophyll-a concentrations also dominate in those regions with dense cloud cover, coastlines and turbid coastal waters **–** a combination of cloud pixels not masked, or pixels affected by nearby clouds alongside a simplistic (band ratio) algorithm that does not account for changes in the water reflectance due to components other than Chlorophyll-a.
  - Overestimating chlorophyll-a in complex Case 2 waters was noted by Preethi Latha et al. (2014) [RD.14] where OCM-2 L2 LAC data was processed using SeaDAS and chlorophyll algorithms like OC2 and OC4-V4 O'Rielly et al. (1998) [RD.15].
  - The Product Quality Assessment was carried out across three marine sites. There are several sources of uncertainty, but, overall, the OCM-2 Chlorophyll-a concentration product appears to be underrepresenting the natural phytoplankton variability. It is difficult to assess the cause as the L2 Bottom of Atmosphere (**BOA**) radiance/reflectance product is not provided as part of the L2C product. Still, by increasing this analysis to a higher number of locations in future reports, we will be able to provide statistical comparison details. Lower chlorophyll estimates, than expected in open ocean waters, were reported by Shanthi *et al.* (2013) [RD.16] where cloud-free L2 processed, OCM data covering the southwest Bay of Bengal demonstrated underestimates for high (in-situ) chlorophyll concentrations and overestimates the low (in-situ) chlorophyll concentrations.

These findings potentially limit the applicability of the OceanSat-2 data in terms of it being classed as a 'Climate Quality' dataset. However, the derived biogeochemical products are comparable to several other ocean colour missions and so are of value to more operational applications.

This report is the final OceanSat-2 Technical Note to be generated within the EDAP contract. Going forward, the aim is to continue to expand the quarterly reporting within the ESA Quality Assurance for Earth Observation (**QA4EO**) contract to include an increasingly more in-depth analysis of the product quality. An increased number of in-situ validation points allows the report to reach the Committee for Earth Observation Satellites (**CEOS**) Land Product Validation Sub-group Stage 1 Validation, where product accuracy is assessed from a small (typically < 30) set of locations and periods by comparison with in-situ or other suitable reference data [RD.17]. The validation approach will continue to follow the marine approach of that defined in [RD.18].

[End of Document]