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Sentinel-3 OLCI L2 Ocean Colour Collection-3 and ongoing developments

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EUMETSAT

24 May 2022

Sentinel-3 OLCI Level-2 Ocean Colour Collection-3 product status

Collection-3 in operations

- v. 3.00 since **16 Feb 2021**
- v. 3.01 since **28 Apr 2021** with two minor updates
- v. 3.02 since **19 Apr 2022** with new processor naming

Collection-3 improvements summary

- High consistency between OLCI-A and OLCI-B
- Open water chlorophyll within mission requirements
- Improved product retrievals over turbid waters
- Reduced «salt and pepper» noise in products

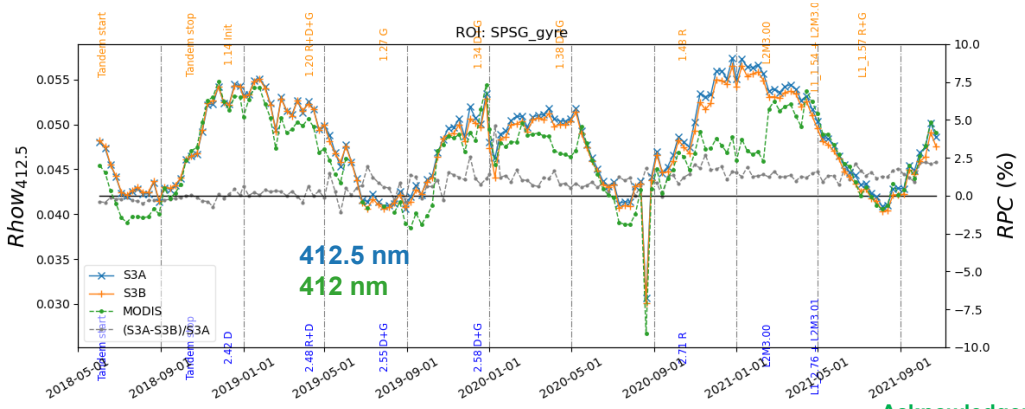
Collection-3 user validation support

- Many validation collaborations during the Collection-3 development with
  - Sentinel-3 Validation Team-OC (S3VT-OC)
  - OLCI/SYN Quality Working Group members (QWG)
  - OC-TAC Copernicus Marine Environment Monitoring Service (CMEMS)
- Peer-reviewed papers published

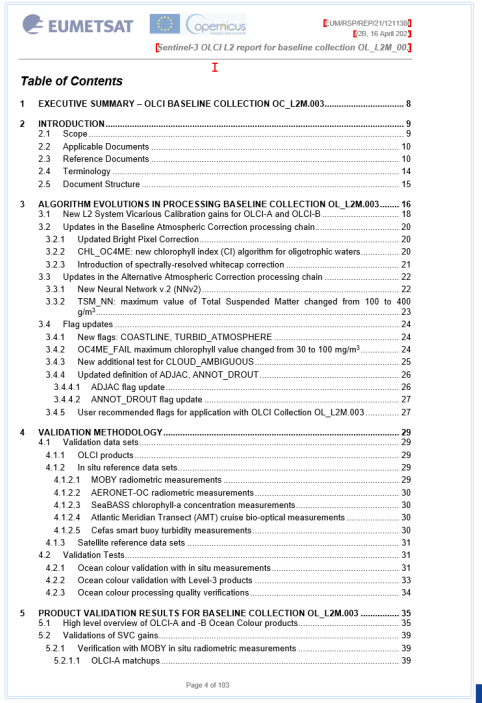
Collection-3 detailed documentation online

- Collection-3 Report (EUM/RSP/REP/21/1211386): *https://www.eumetsat.int/media/47794*
- Ocean Colour Services page: *https://www.eumetsat.int/ocean-colour-services*

OLCI-A, **OLCI-B**, **MODIS-A** water reflectance time series over the **South Pacific Gyre**



Acknowledgements to NASA for MODIS-A products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[EUMRSP/REP/21/1211386]
[CDI, 16 April 2021]
[Sentinel-3 OLCI L2 report for baseline collection OL_L2M_003]

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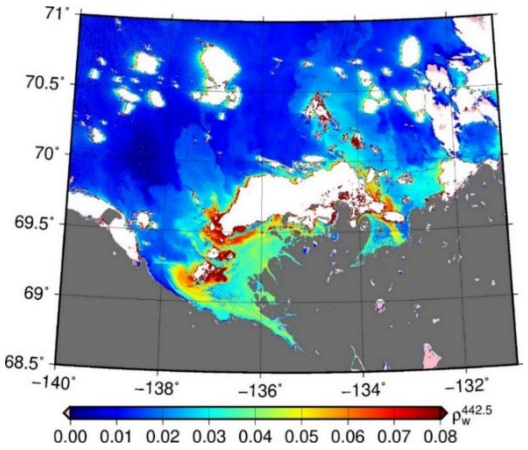
2017-06-20, 442.5nm, Mackenzie River estuary



Sentinel-3 OLCI Level-2 Ocean Colour Collection-3 main updates

New L2 System Vicarious Calibration gains

- OC-SVC gains updated for OLCI-A
- OC-SVC new gains for OLCI-B

→ all updates follow OLCI/SYN QWG and S3VT-OC recommendations and requests from OC-TAC CMEMS

Updated L2 Marine algorithms

- Baseline Atmospheric Correction processing chain (clear water products)
  - Updated Bright Pixel Correction (Solvo, HYGEOS, HEREON)
  - New Chlorophyll Index algorithm for oligotrophic waters (Hu *et al*., 2012; Wang and Son, 2016)
  - Spectrally-resolved whitecap correction introduced (Frouin *et al*., 1996; Fougnie 2020)
- Alternative Atmospheric Correction processing chain (complex waters, NN products)
  - New Neural Network v.2 (Brockmann Consult / S3 MPC; NNv.2 is matching C2RCC in SNAP)
  - Updated scaling of Total Suspended Matter to allow retrievals to 400 g/m^3
- Flags
  - New additional test for CLOUD_AMBIGUOUS (Wang and Shi, 2006)
  - OC4ME_FAIL update to allow chlorophyll retrieval to 100 mg/m^3
  - New flags: COASTLINE, TURBID_ATMOSPHERE
  - Updated definition of ANNOT_DROUT, ADJAC

Updated list of recommended flags for Baseline Atmospheric Correction products

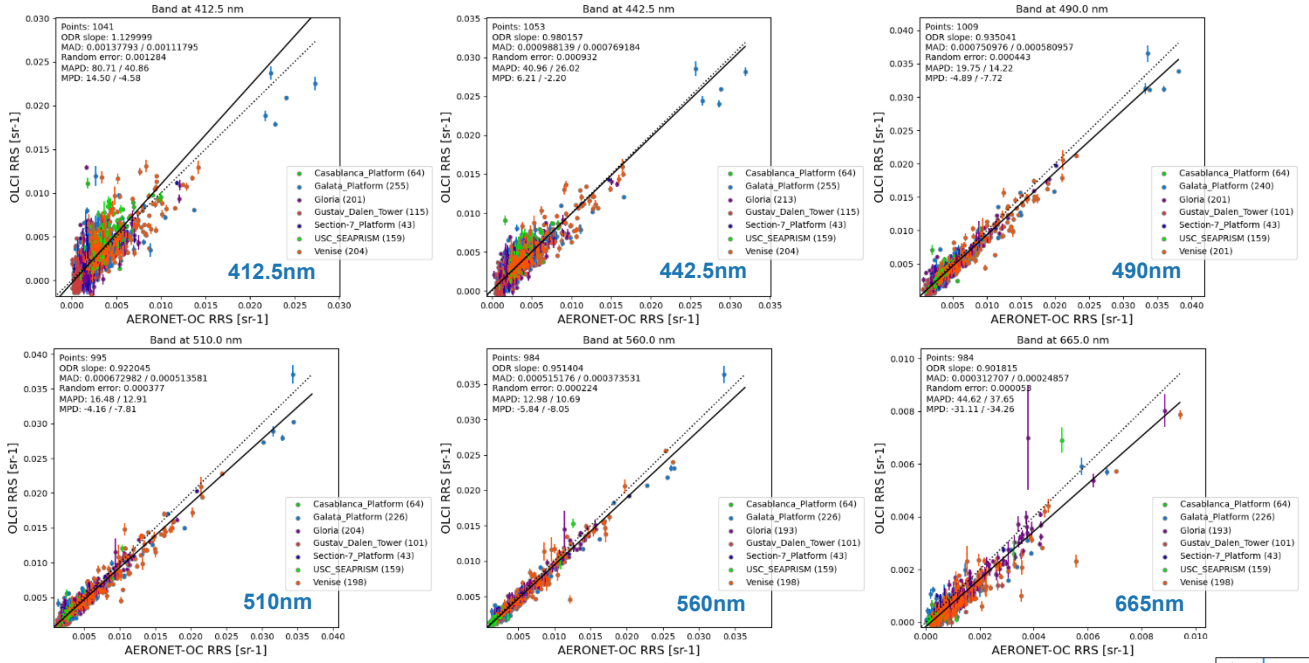
- CLOUD, CLOUD_AMBIGUOUS, CLOUD_MARGIN, INVALID, COSMETIC, SATURATED, SUSPECT, HISOLZEN, HIGHGLINT, SNOW_ICE, AC_FAIL, WHITECAPS, ADJAC, RWNEG_O2, RWNEG_O3, RWNEG_O4, RWNEG_O5, RWNEG_O6, RWNEG_O7, RWNEG_O8
- + flags specific to a product e.g. OC4ME_FAIL

Operationally available from 16-Feb/28-Apr 2021

Reprocessed complete timeseries available soon

Sentinel-3 OLCI L2 Collection-3 validation with AERONET-OC

OLCI-A



OLCI-A previous status

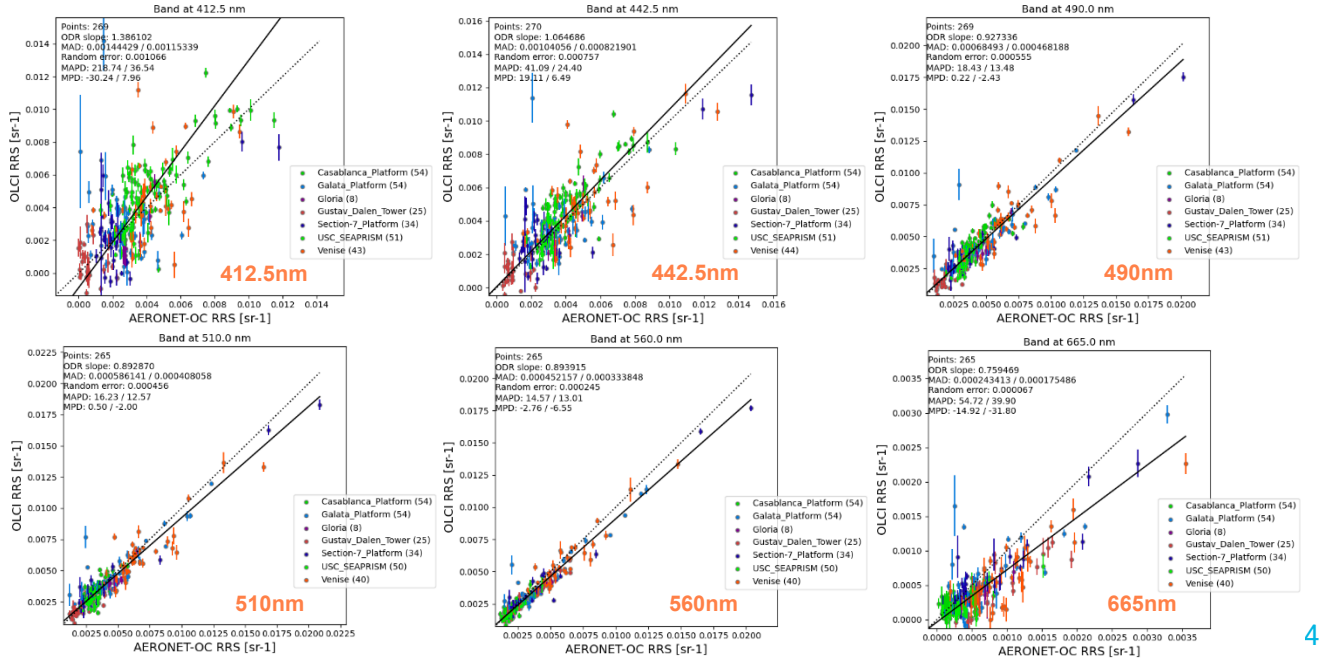
- Residual water reflectance non-compliances

Collection-3 status

- Significant impact in the blue bands with more accurate spectral shape

Acknowledgements to AERONET-OC PIs:
Giuseppe Zibordi and Burton Jones

OLCI-B



OLCI-B previous status

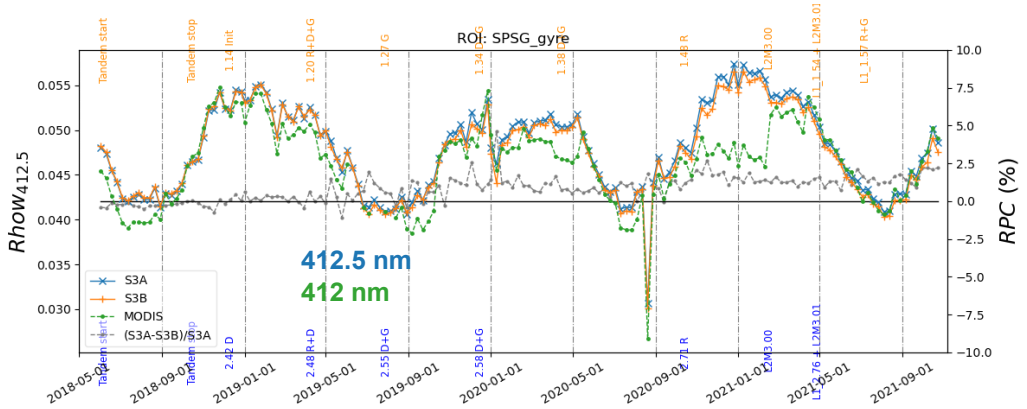
- Water reflectance full non-compliance

Collection-3 status

- Significant reduction of positive biases which were observed before
- Performance of OLCI-A and OLCI-B is now highly consistent

OLCI L2 Collection-3 water reflectance comparisons with MODIS-Aqua

OLCI-A, **OLCI-B**, **MODIS-A** water reflectance time series over the **South Pacific Gyre**



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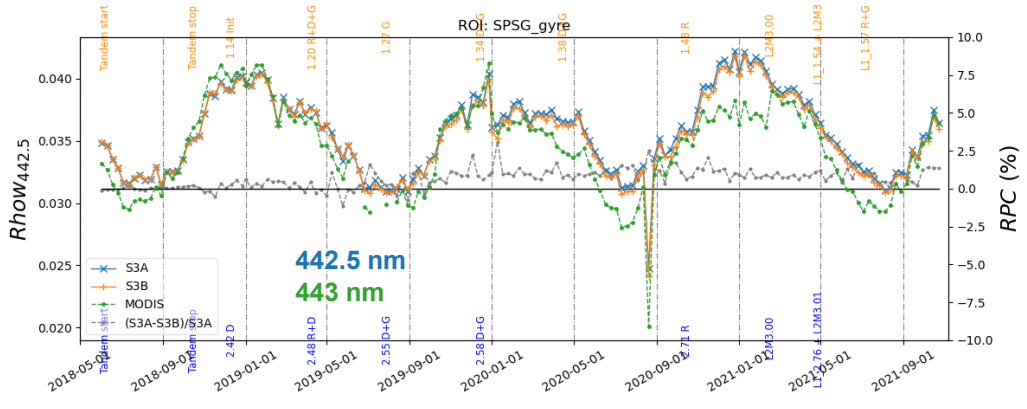
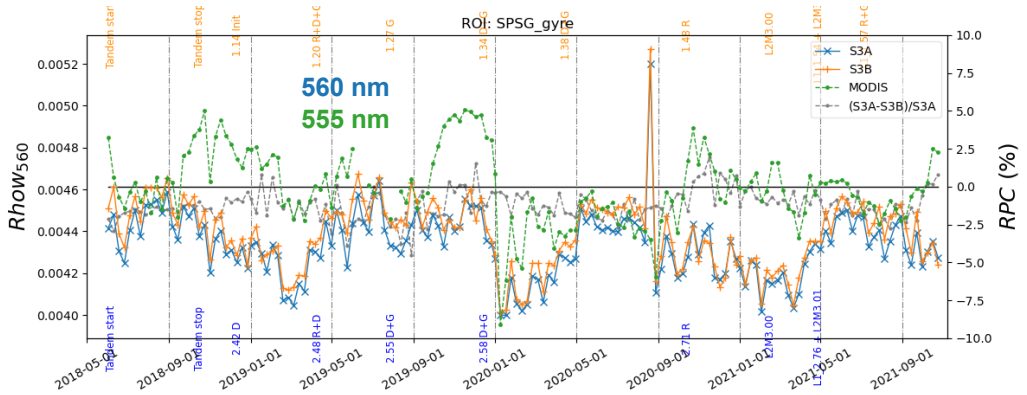
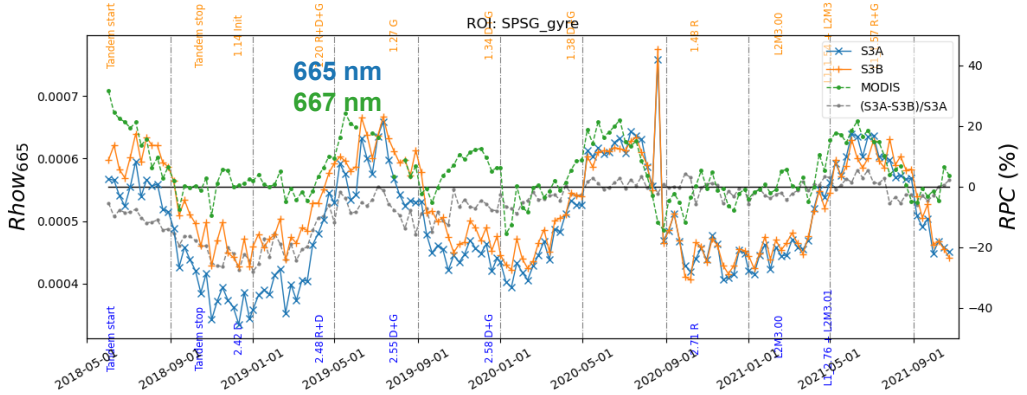


Time series derived from
- Level-3 8-day binned products at 9km resolution
- Only matching bins between sensors

OLCI-A, **OLCI-B**, **MODIS-A** water reflectance time series over the **South Pacific Gyre**



OLCI-A, **OLCI-B**, **MODIS-A** water reflectance time series over the **South Pacific Gyre**



Acknowledgements to NASA for MODIS-A products

OLCI-A+B previous status

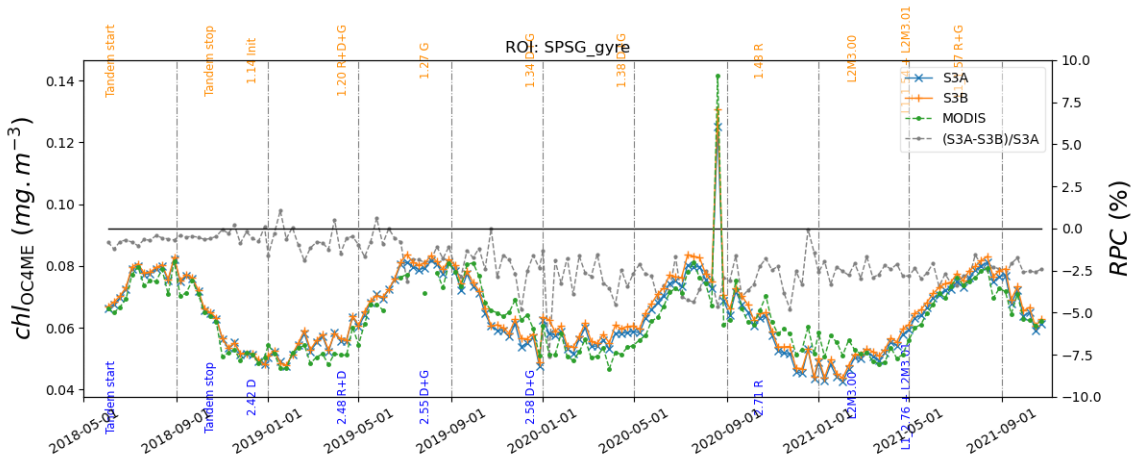
- Large differences between OLCI-A and OLCI-B of ~10%

Collection-3 status

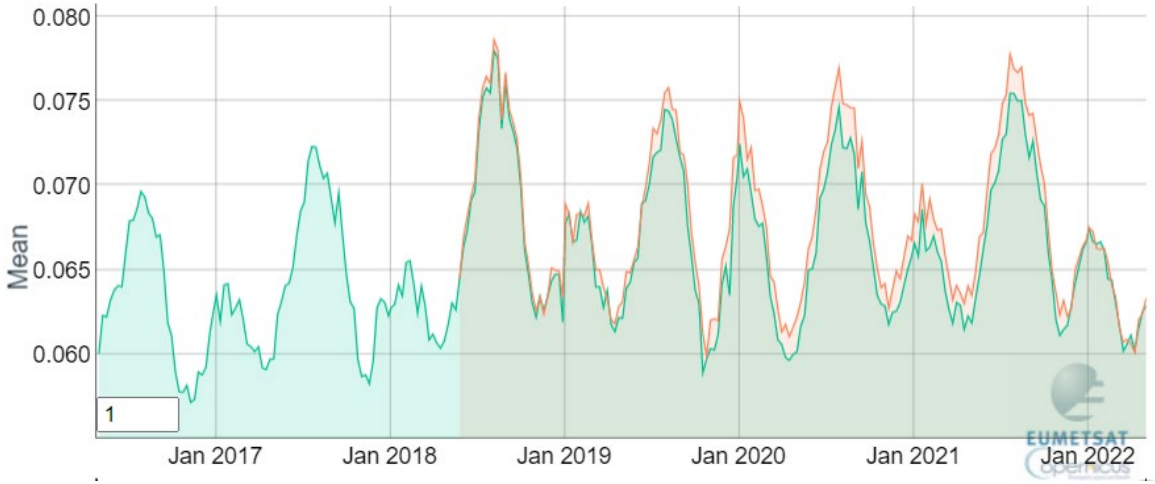
- **Excellent consistency between OLCI-A and OLCI-B**, while OC-SVC gains were derived independently for both sensors *https://www.eumetsat.int/ocean-colour-system-vicarious-calibration-tool*
- Good agreement with MODIS-A, differences mostly explained by spectral bands differences

OLCI L2 Collection-3 algal pigment concentration mission intercomparisons

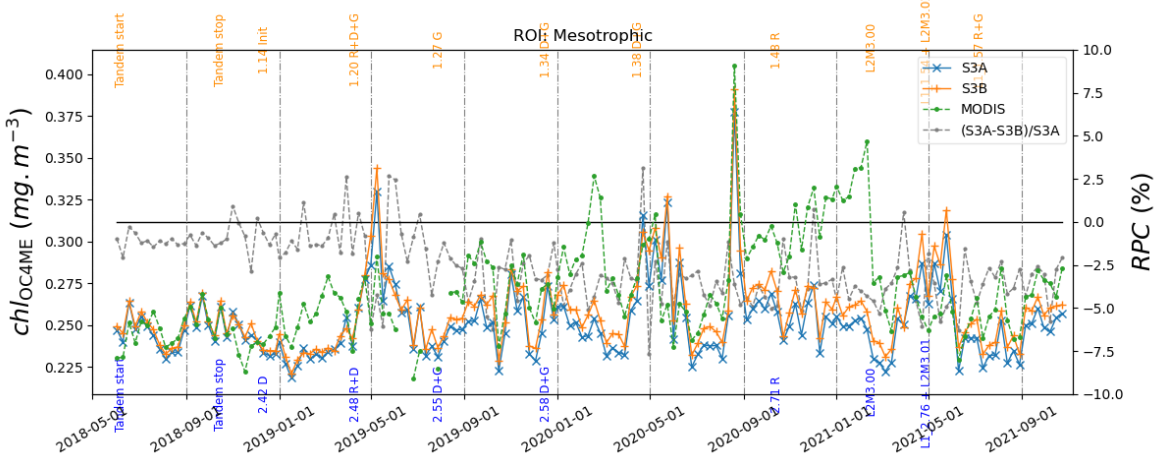
OLCI-A, **OLCI-B**, **MODIS-A** chlorophyll time series over the **South Pacific Gyre**



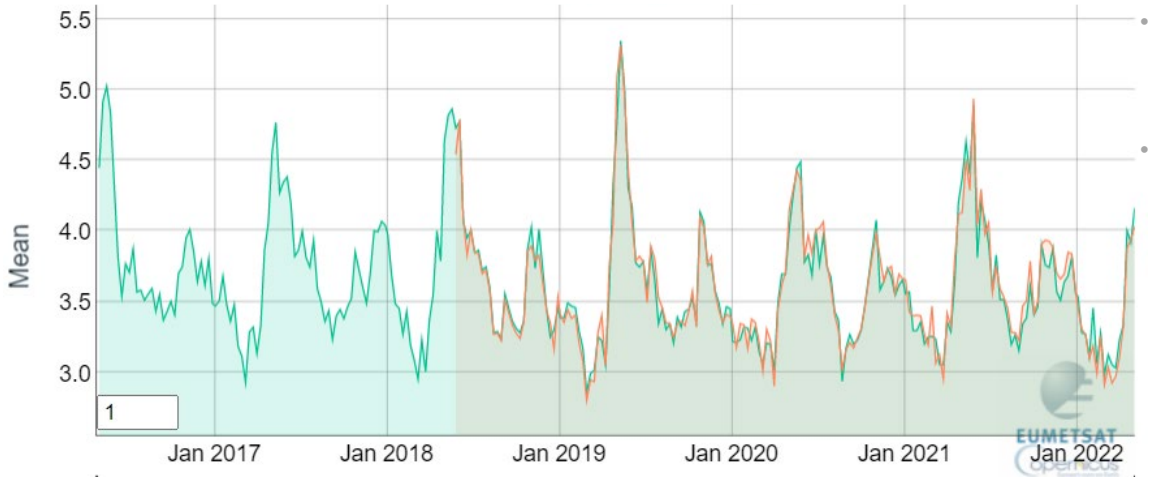
OLCI-A, **OLCI-B** chlorophyll time series over **Oligotrophic Waters**



OLCI-A, **OLCI-B**, **MODIS-A** chlorophyll time series over **Mesotrophic Waters**



OLCI-A, **OLCI-B** chlorophyll time series over **Eutrophic Waters**



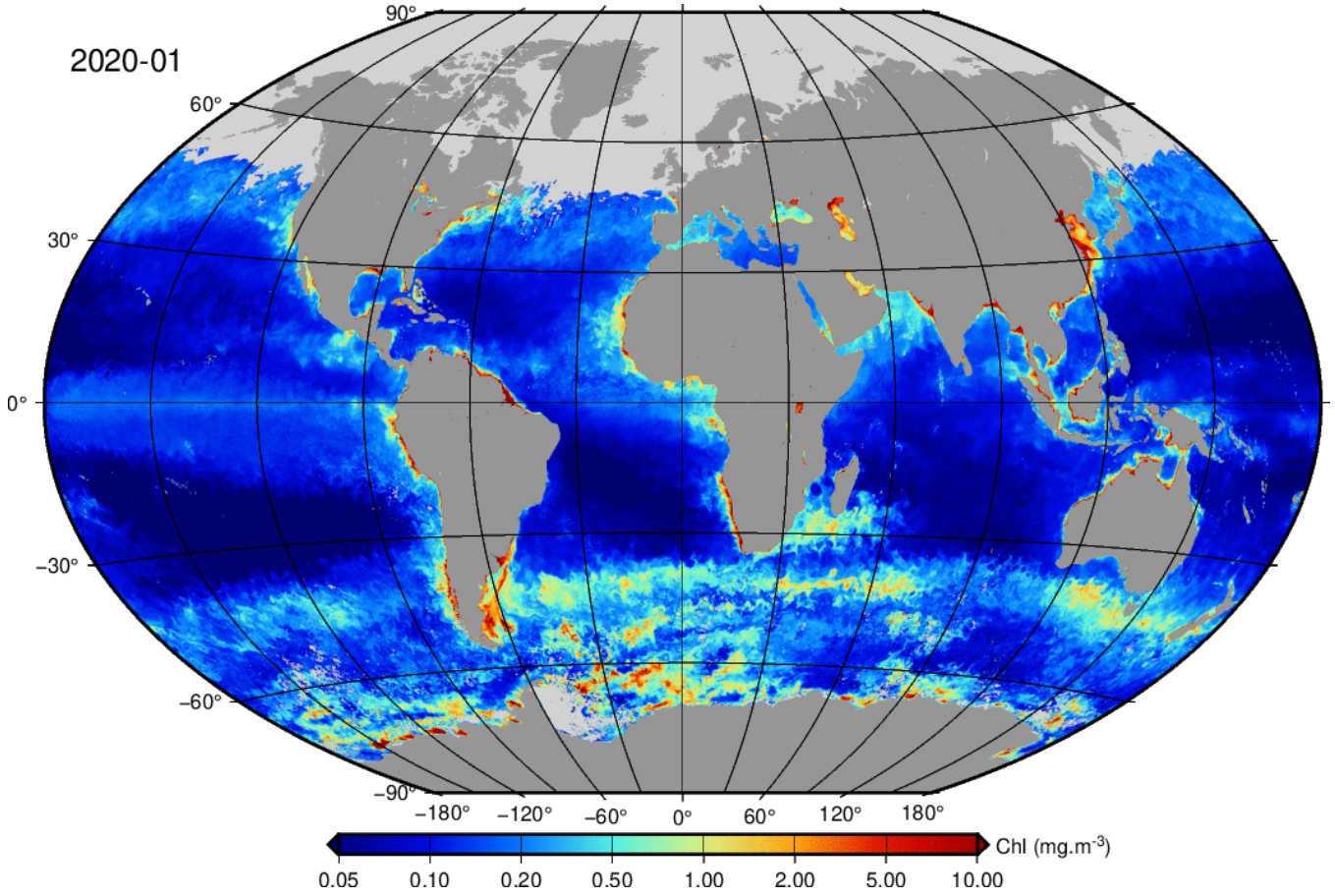
Time series derived from
- Level-3 8-day binned products at 9km resolution
- Complete time series (non-overlapping bins)

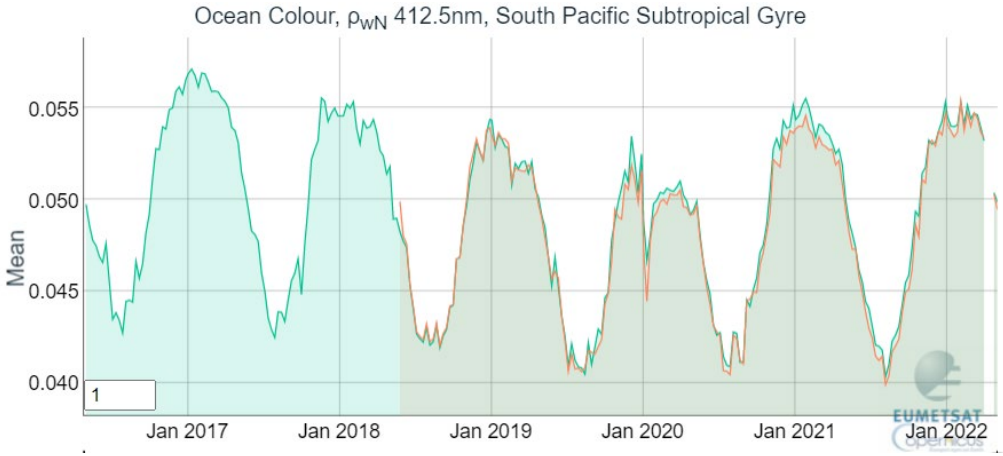
Acknowledgements to NASA for MODIS-A products

- Oligotrophic waters: chl < 0.1 mg/m^3
- Mesotrophic waters: 0.1 ≤ chl < 1 mg/m^3
- Eutrophic waters: chl ≥ 1 mg/m^3

METIS-OC

- Monitoring and Evaluation of EUMETSAT operational level-2 Ocean Colour products

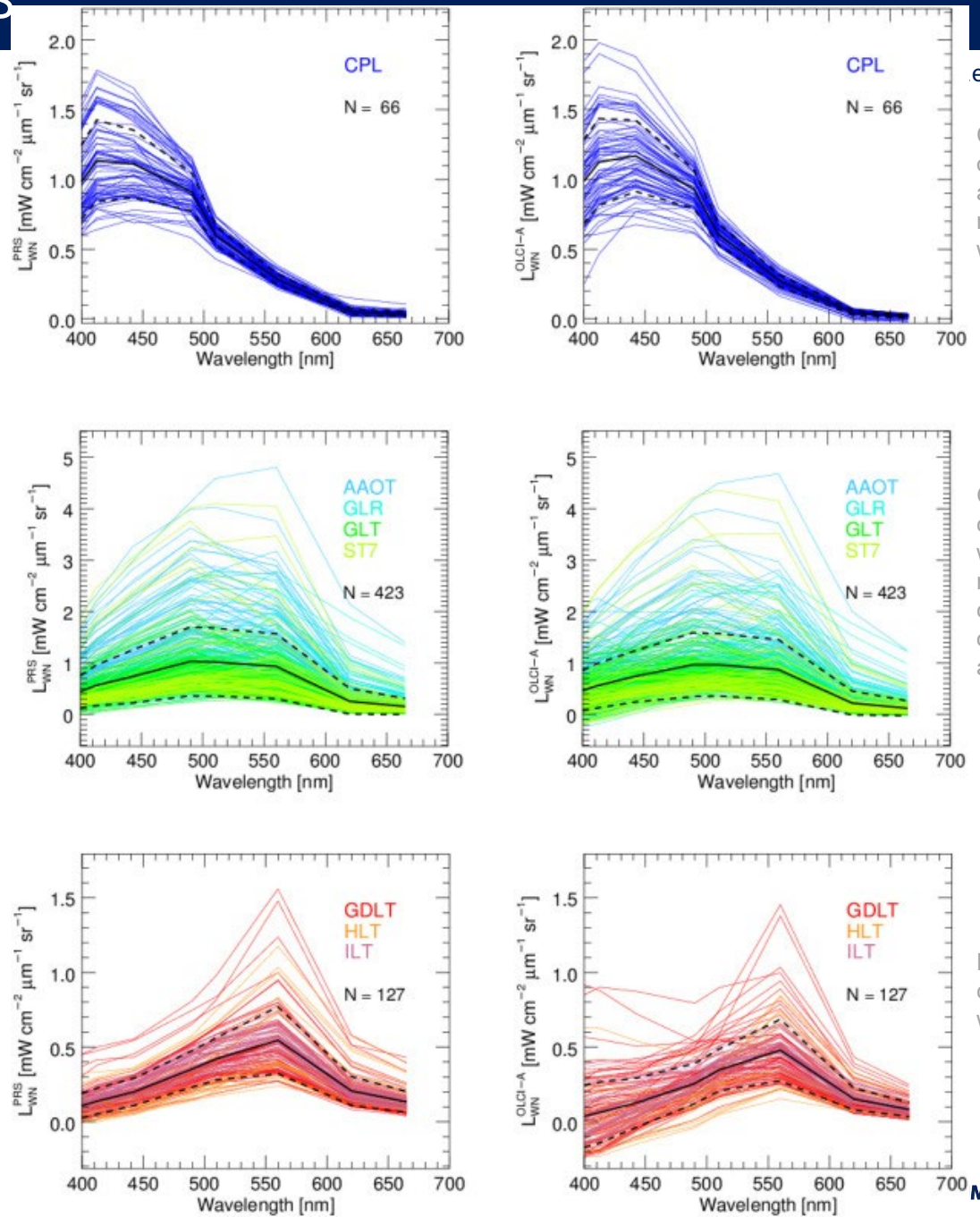




OLCI Collection-3 validation papers

Collection-3 OLCI L2 validation papers

- Zibordi *et al*., 2022, RSE: https://doi.org/10.1016/j.rse.2022.112911
- Cazzaniga *et al*., 2022, IEEE GRSL: https://doi.org/10.1109/LGRS.2021.3136291
- Tilstone *et al*., 2021, RSE: https://doi.org/10.1016/j.rse.2021.112444
- Tilstone *et al*., 2022, MDPI RS: https://doi.org/10.3390/rs14010089
- Vanhellemont and Ruddick, 2021, RSE: https://doi.org/10.1016/j.rse.2021.112284



Curtesy Zibordi *et al*., 2022

Clear oligotrophic and mesotrophic waters

Generic complex waters with moderate concentrations of sediments and CDOM

High CDOM concentration waters

Fulfilment of Sentinel-3 Mission Requirements – OLCI L2 Ocean Colour

Parameter	Requirement Threshold, [goal]	OLCI-A current status	OLCI-B current status	Comments
Marine reflectance@442nm	5.10^{-4}	Not Compliant 7.10^{-4}	Not Compliant 8.10^{-4}	Validation numbers are for coastal AERONET-OC sites with higher optical complexity. Open ocean inter-comparisons with MODIS-A indicate < 5.10^{-4}.
Water-leaving radiance	5%	Partly Compliant <5% 400-442nm <8% 490-560nm	Partly Compliant <5% 490-510nm <8% 412-560nm	Validation numbers are for coastal AERONET-OC sites with higher optical complexity. Open ocean verifications at MOBY indicate < 5% 400 – 620 nm.
Photosynthetically Active Radiation	5%	Preliminary	Preliminary	No validation measurements for instantaneous PAR
Diffuse attenuation coefficient	5%	Preliminary	Preliminary	No validation measurements
Chlorophyll	70% [10%] (case 2 waters) 30% [10%] (case 1 waters)	Compliant	Compliant	Limited validation measurements. Results based on matchups in oligotrophic and mesotrophic waters, and large-scale mission inter-comparisons.
Total Suspended Matter	70% [10%] (case 2 waters) 30% [10%] (case 1 waters)	Preliminary	Preliminary	Limited validation measurements. S3VT-OC show TSM improvement
Coloured Dissolved Organic Matter	70% [10%] (case 2 waters) 50% [10%] (case 1 waters)	Preliminary	Preliminary	No validation measurements

Reference:

Sentinel-3: Mission Requirements Document, 2007, *EOP-SMO/1151/MD-md* Iss.2, table 7, §5.3.2

OLCI L2 Collection-3 Report includes:

- guidance on Mission Requirements, as some Requirements are not specific to optical water types or wavelengths
- detailed validation results
- known product limitations
- *https://www.eumetsat.int/media/47794*

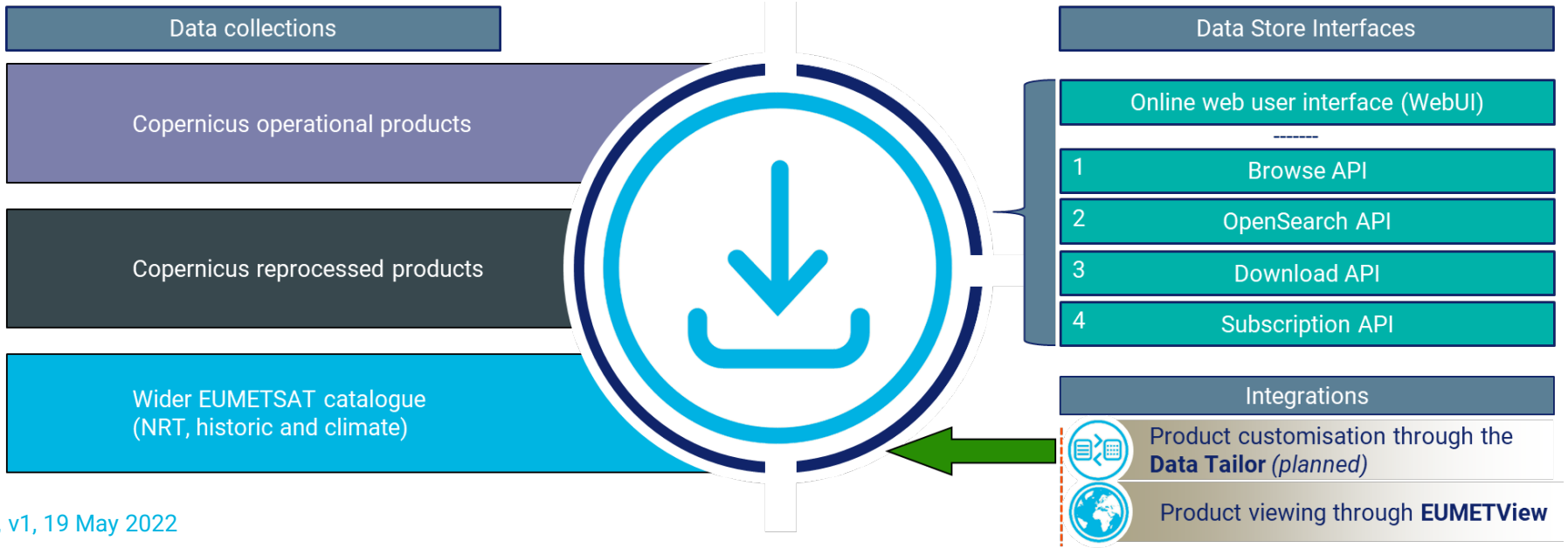
Sentinel-3 OLCI reprocessed data and EUMETSAT Data Store services

Collection-3 full mission reprocessing

- Reprocessed OLCI-A and OLCI-B available internally at EUMETSAT
- Reprocessed data provided to CMEMS OC-TAC
- Reprocessed data provided to many S3VT-OC teams
- Reprocessed data available to all users in Q3 2022 (TBC)
- **Please contact us if you would like access to subsets of OLCI reprocessed data sooner:**
  - David.Dessailly@eumetsat.int
  - Ewa.Kwiatkowska@eumetsat.int

EUMETSAT Data Store – a single online access point for all operational and reprocessed data

- EUMETSAT Data Store: *https://data.eumetsat.int*
- Currently available are OLCI operational data from 01 January 2021 to present
- Migration of OLCI reprocessed data to the Data Store is being done for the first time and has been taking time, but all OLCI data should be available in Q3 2022 (TBC)
- CODA will be discontinued the end of September 2022
- *https://www.eumetsat.int/sentinel-3-data-coming-data-store*



Sentinel-3 OLCI Collection-3 limitations and ongoing development

Collection-3 User feedback:

Collection-3 is a good achievement but there is room for improvements

- Known product open issues and limitations are described in Collection-3 Report *https://www.eumetsat.int/media/47794*

Ocean Colour product open issues and the need for improvements have been identified

- Water Reflectance products only partially meet the S3 Mission Requirements
- Problems with the standard atmospheric correction, including aerosol model limitations with Angstrom ≤ 1.6
- Large uncertainties are still present in complex waters, particularly in CDOM-dominated waters, e.g. Baltic Sea
- Geometry or camera dependences are showing as cross-track product biases
- Underestimated NIR water reflectances in coastal waters with low-to-moderate turbidities, e.g. in 753, 778 nm bands
- Residual L2 flag limitations
- L2 ‘error’ uncertainty parameters need to be applied with caution as they are not validated and do not include L1 uncertainty budget

Ocean Colour product evolution and development are ongoing

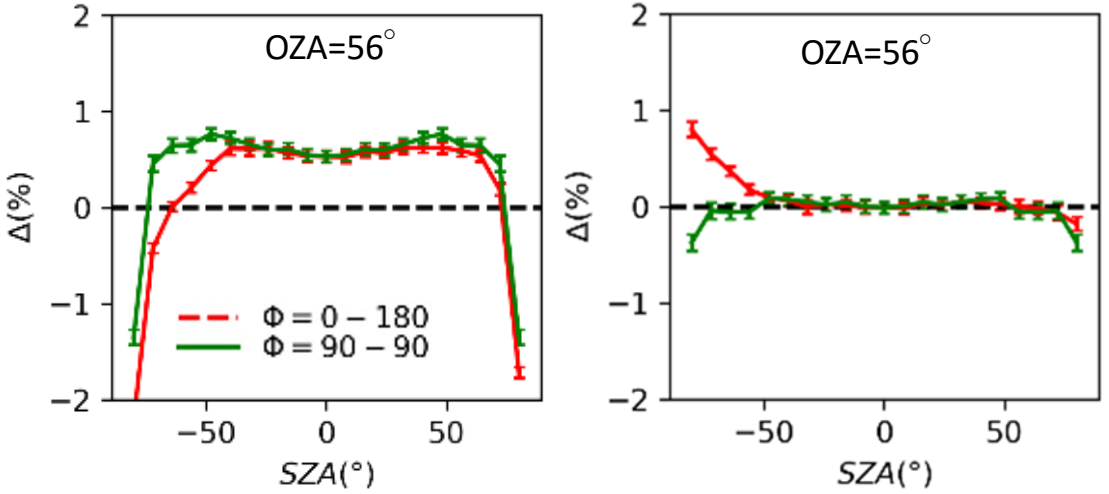
- Redevelopment of the Standard Atmospheric Correction
- BRDF-correction development for water reflectance products
- Operational implementation of new OLCI L2 products, IOP and Fluorescence
- Additional Ocean Colour algorithm evolutions, e.g. flags, chlorophyll product, optical water types

OC-SAC key new elements

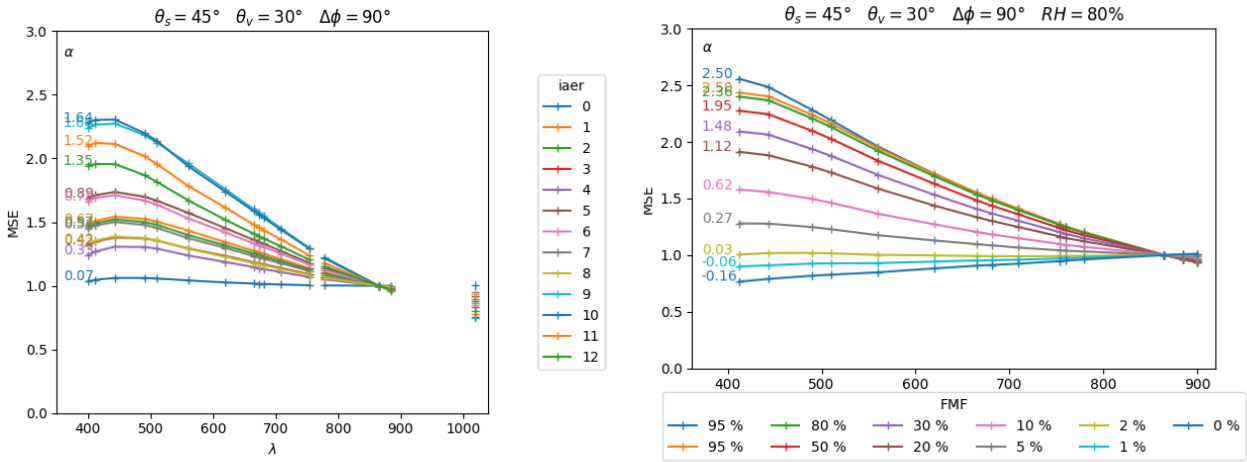
- Radiative Transfer Modelling at detector wavelength, no smile correction
- Atmosphere Spherical effect, mainly for the molecular Rayleigh scattering
- Aerosol vertical profile, through a rough estimate of aerosol layer height with O_2-absorption bands
- Aerosol standard models from Ahmad *et al.,* 2010, with continuous discretization
- Extension of standard aerosol models to strongly absorbing models with increased refractive index
- Aerosol detection with 6 NIR bands (instead of 2), and uncertainty estimates
- New Rayleigh and atmospheric pressure correction based on Rayleigh optical thickness

solVo HYGEOS

Plane Parallel → Spherical Shell modelling



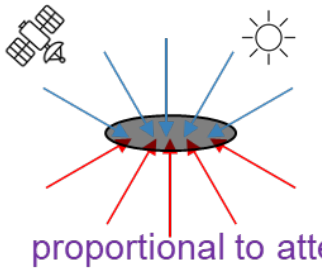
OLCI operational models → Ahmad *et al.*, 2010



BRDF correction development for clear and complex water reflectance

BRDF correction key new elements

- Several tested BRDF models:
  - Morel *et al.*, 2002; Park and Ruddick, 2005; Lee *et al.*, 2011; He *et al.*, 2017; Twardowski and Tonizzo, 2018
- Focus on Twardowski and Tonizzo, 2018 (T18)
  - the most analytical of all models
  - based on simplified expression of the radiative transfer equation (RTE) from Zaneveld, 1995
  - includes Raman scattering
  - modular and customizable
  - theoretically suitable for all waters, clear and complex



$$\cos\theta \frac{dL_u(\theta,\phi,z)}{dz} = L_u^*(\theta,\phi,z) - c(z)L_u(\theta,\phi,z)$$

variation = source - attenuation

proportional to attenuation

upper + lower hemispheres

EVALUATION IN PROGRESS

$$K_{Lu}L_u(\theta,\phi,z)\cos\theta = f_b(\theta,\phi,z)\frac{b_b(z)}{2\pi}E_{od}(z) + f_L(\theta,\phi,z)L_u(\theta,\phi,z)b_f(z) - c(z)L_u(\theta,\phi,z)$$

$$\frac{L_u(\theta_s,\theta_v,\phi)}{E_{od}} = \frac{\beta(\psi)}{\cos\theta_v K_{Lu}(\theta_s,\theta_v,\phi) + c - f_L(\theta_s,\theta_v,\phi)b_f}$$

Solving for $\frac{L_u(\theta_s,\theta_v,\phi)}{E_{od}}$

OLCI water Inherent Optical Property RR test products available (IOP)

OLCI IOP test products

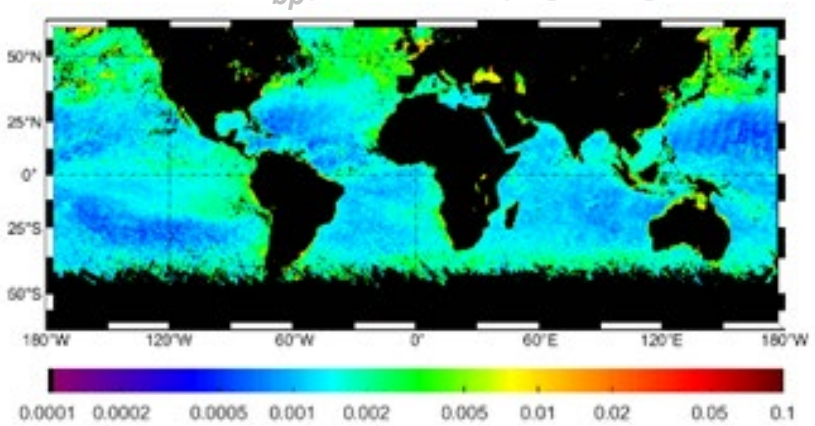
- $a_{nw}(\lambda)$, $b_{bp}(\lambda)$, $a_{phy}(\lambda)$, $a_{cdm}(\lambda)$, $a_{cdom}(\lambda)$, $K_d(\lambda)$, b_{bp} spectral slope, optical water class
- a and b_{bp} are at 442.5 nm and K_d is at 490 nm
- Description*: https://www.eumetsat.int/S3-OLCI-IOP*
- SNAP toolbox: *http://s3vt.skytek.com/group/s3vt-oc/home*
- Gitlab source code: *https://gitlab.eumetsat.int/eumetlab/oceans/ocean-science-studies/olci-iop-processor*

Jorge *et al.*, 2021 RSE IOP
Bonelli *et al.*, 2021 RSE CDOM

IOP OLCI-A and OLCI-B RR time series is available from mission start to March 2022

- Distribution via ftp for bulk download (~25TB)
  - Access available to S3VT
  - Credential from David.Dessailly@eumetsat.int
- EUMETSAT Data Store, from end of Q3 2022 (TBC)

OLCI $b_{bp}(442.5\ nm)$ [1/m]



- One NetCDF file added:
  - iop_lsd.nc
- Product name: Non-standard SAFE name
  - S3A_OL_2_WRR____20180312T183717_20180312T192111_20211015T072412_2634_029_013__IOP_MAR_D_NT_003.SEN3
- Attributes (source, disclaimer, product_documentation, bibliography) clearly identify the products as «Aspirational»

OLCI Fluorescence test products available in a toolbox

OLCI Fluorescence test products

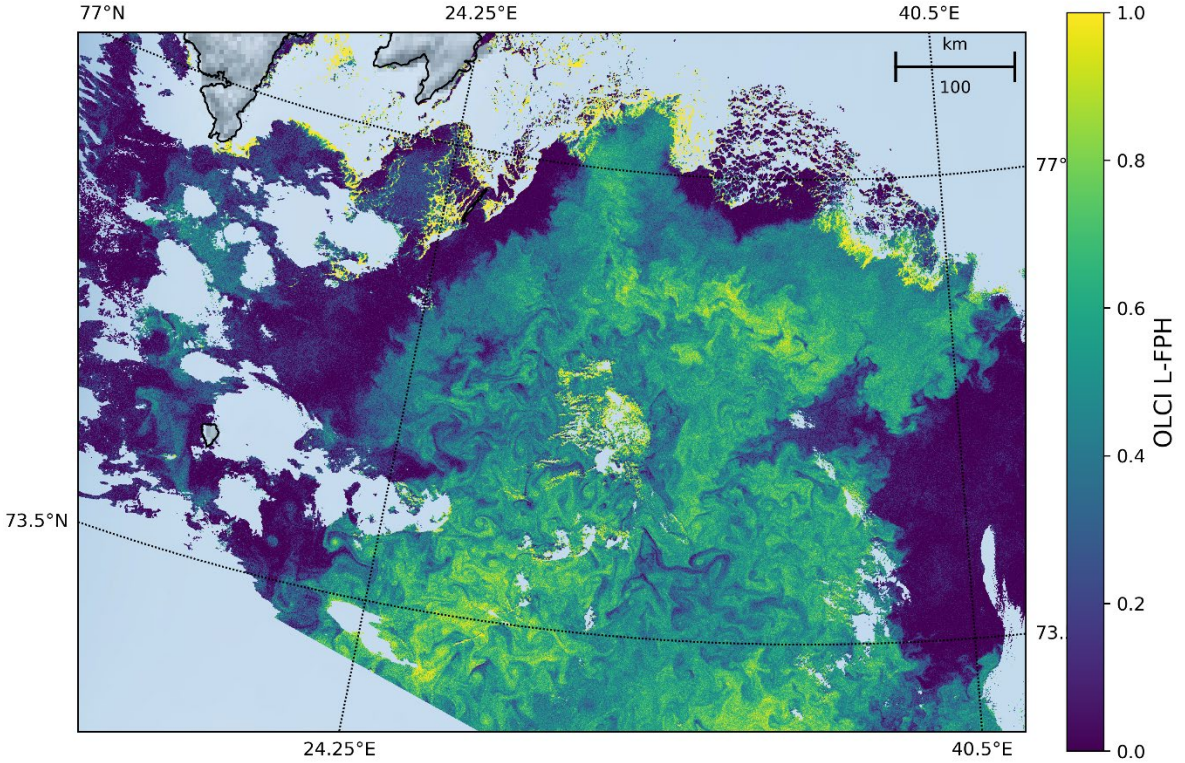
- TOA-radiance and Water-reflectance Fluorescence Peak Height
- Description: *https://www.eumetsat.int/S3-OLCI-FLUO*
- SNAP plugin: *http://s3vt.skytek.com/group/s3vt-oc/home*

Spectral Earth GmbH

Kritten *et al.*, 2020 RS MDPI Fluo

Fluorescence OLCI-A and OLCI-B RR time series will be processed next for user validation

OLCI *Fluorescence Peak Height* in Barents Sea [mW/m²/sr/nm]



Summary

Sentinel-3 OLCI Collection-3 in operations since February 2021, full mission reprocessed and operational data stream available from Q3 2022 (TBC) on EUMETSAT Data Store

- Collection-3 Report *https://www.eumetsat.int/media/47794*
- EUMETSAT Ocean Colour website *https://www.eumetsat.int/ocean-colour-services*
- *https://coda.eumetsat.int* → EUMETSAT Data Store *https://data.eumetsat.int*

OLCI Collection-3 development followed S3VT/QWG/CMEMS recommendations and benefited of validation collaborations

- Collaborations brought higher confidence in the released data products

OLCI Collection-3 is a good achievement but there is room for improvements

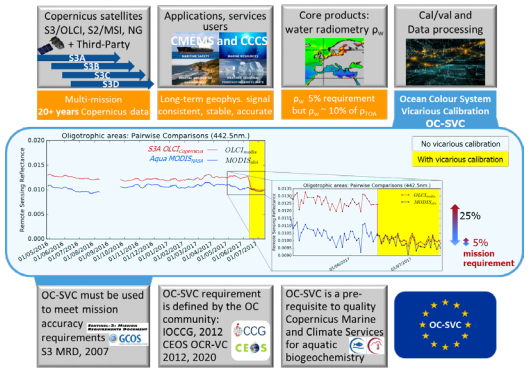
- Known product limitations described in Collection-3 Report *https://www.eumetsat.int/media/47794*

Ocean Colour product evolution and development have been ongoing towards OLCI Level-2 Collection-4 and onwards

- Working towards Collection-4, tentative timeframe of the next two years
- Working towards Collection-5, Day-2 Multi-Mission Modular Ocean Colour processor in longer timeframe

B1.03.3 Riho Vendt

https://frm4soc2.eumetsat.int



Copernicus Programme Ocean Colour System Vicarious Calibration (OC-SVC) infrastructure

https://www.eumetsat.int/OC-SVC

Thank you!

Questions are welcome.