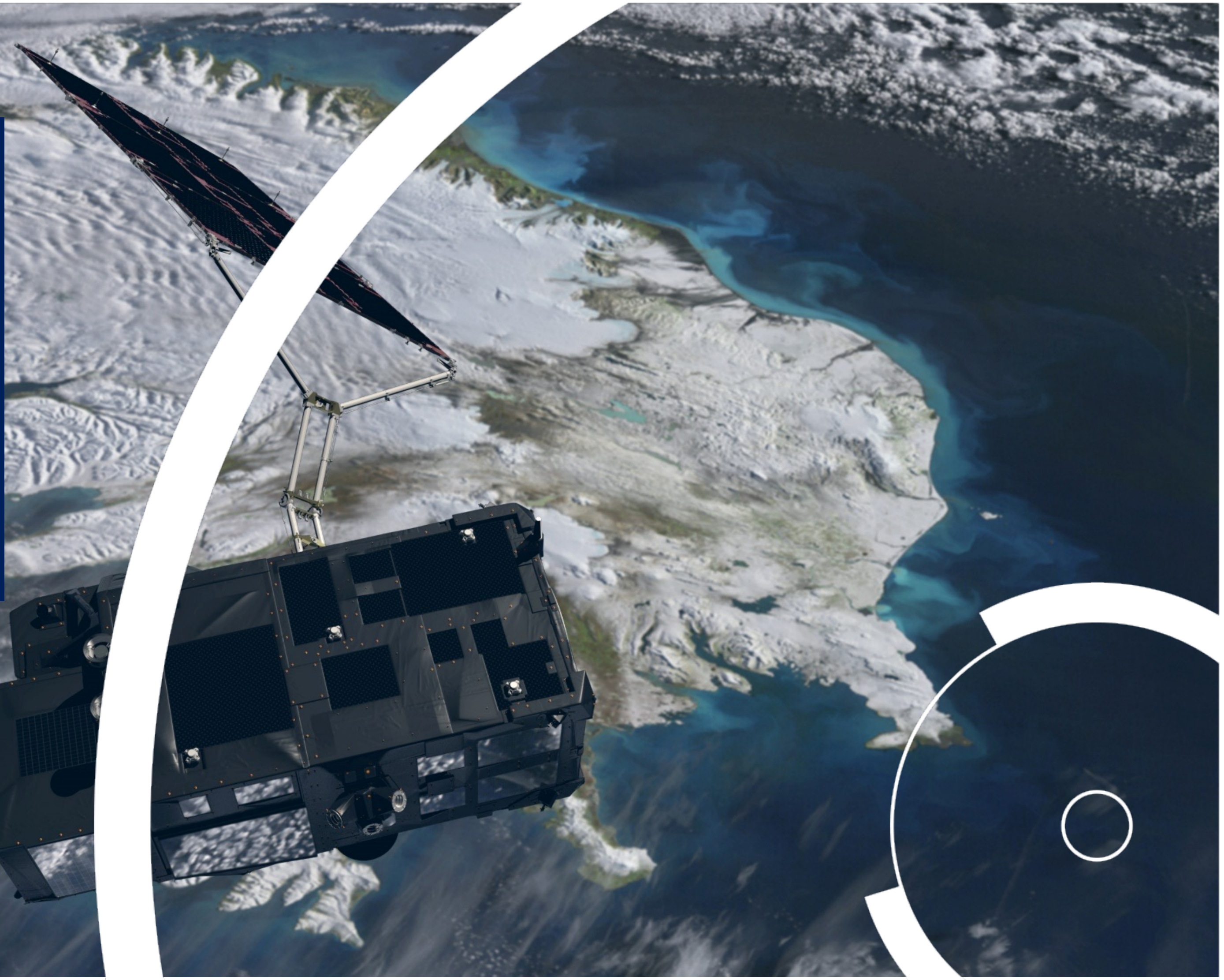
EUMETSAT Agency update

Ewa Kwiatkowska
David Dessailly, Juan Ignacio Gossn, Estelle Obligis

IOCCG-26 Committee Meeting

27 June 2022



EUMETSAT L2 Ocean Colour main activities and tentative planning

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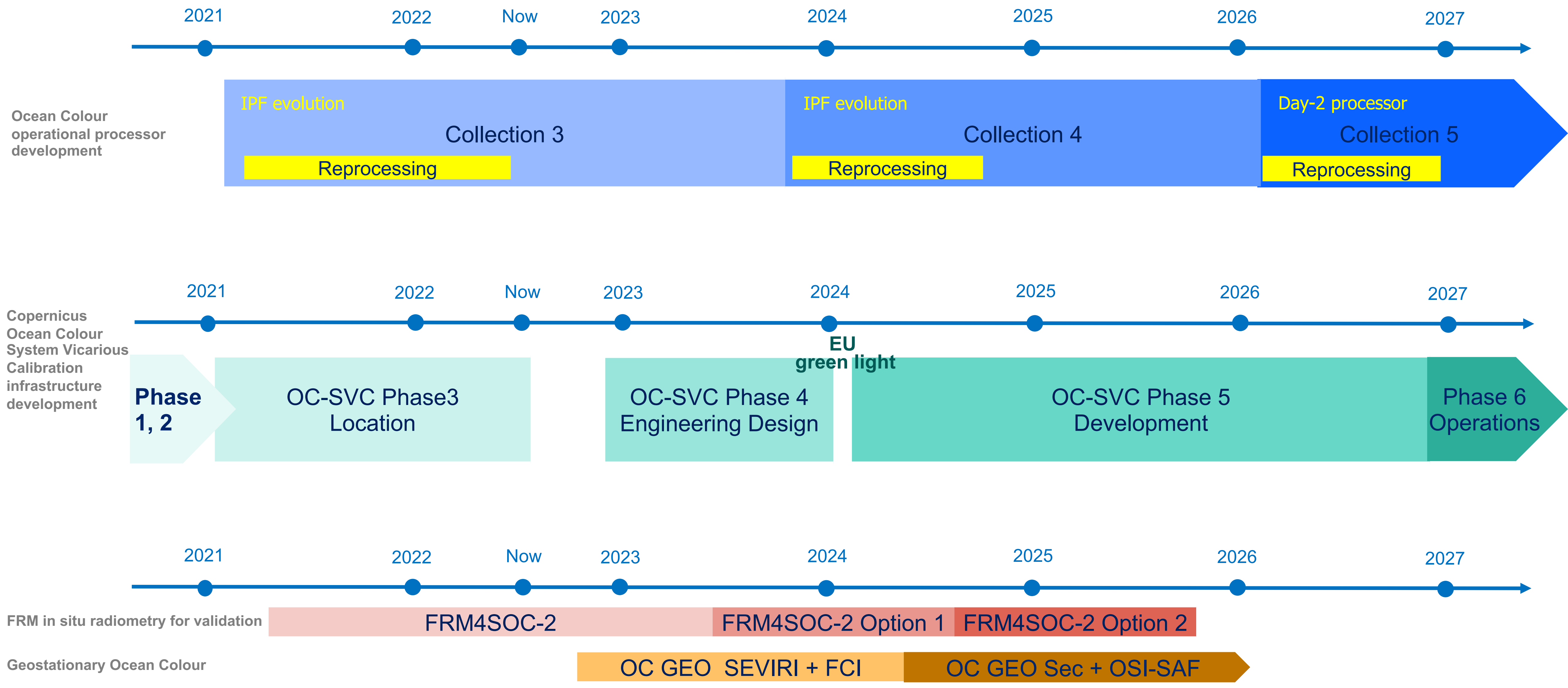


Sentinel-3 OLCI Level-2 Ocean Colour Collection-3 product status

copernicus.eumetsat.int

https://www.eumetsat.int/ocean-colour-services

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

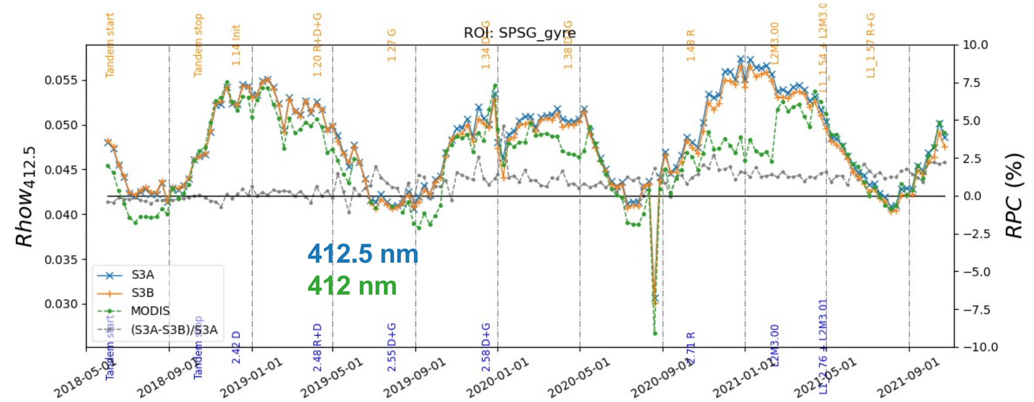
Collection-3 user validation support

- 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

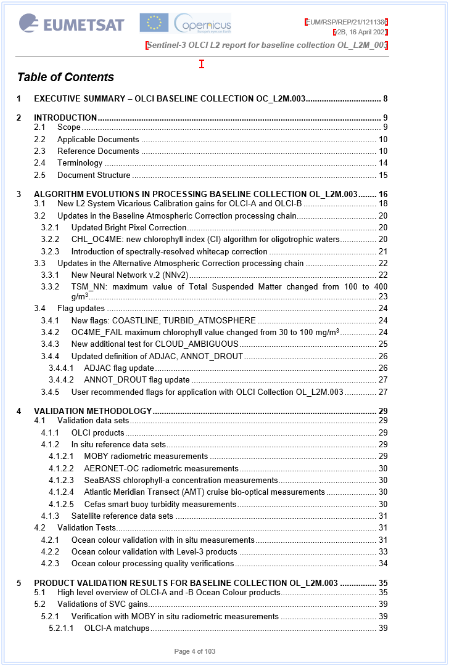
Collection-3 detailed documentation online

- 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


EUMETSAT | Copernicus | EUM/RSP/REP/21/1211386 | v2B, 16 April 2021 | Sentinel-3 OLCI L2 report for baseline collection OL_L2M_003

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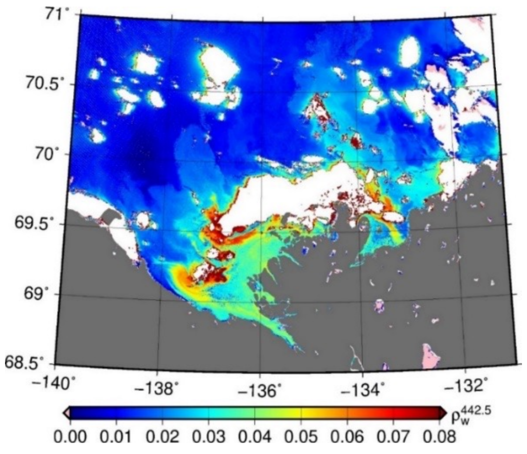
2017-06-20, 442.5nm, Mackenzie River estuary



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

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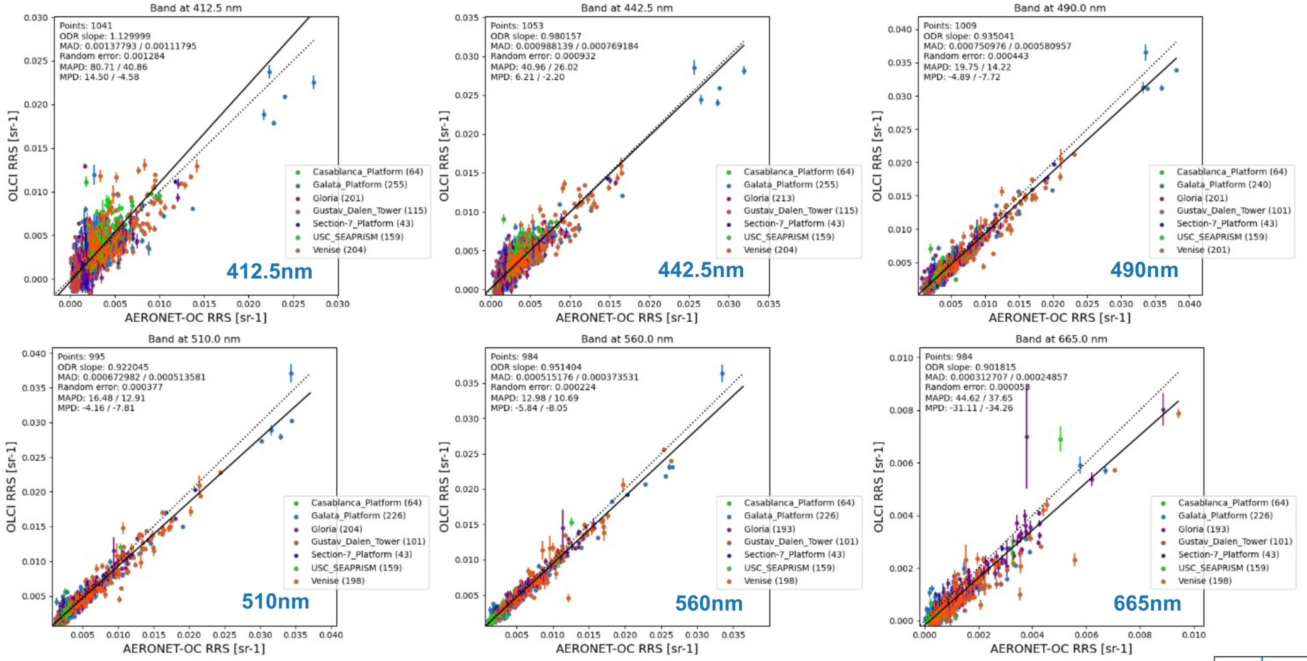
https://www.eumetsat.int/media/47794

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

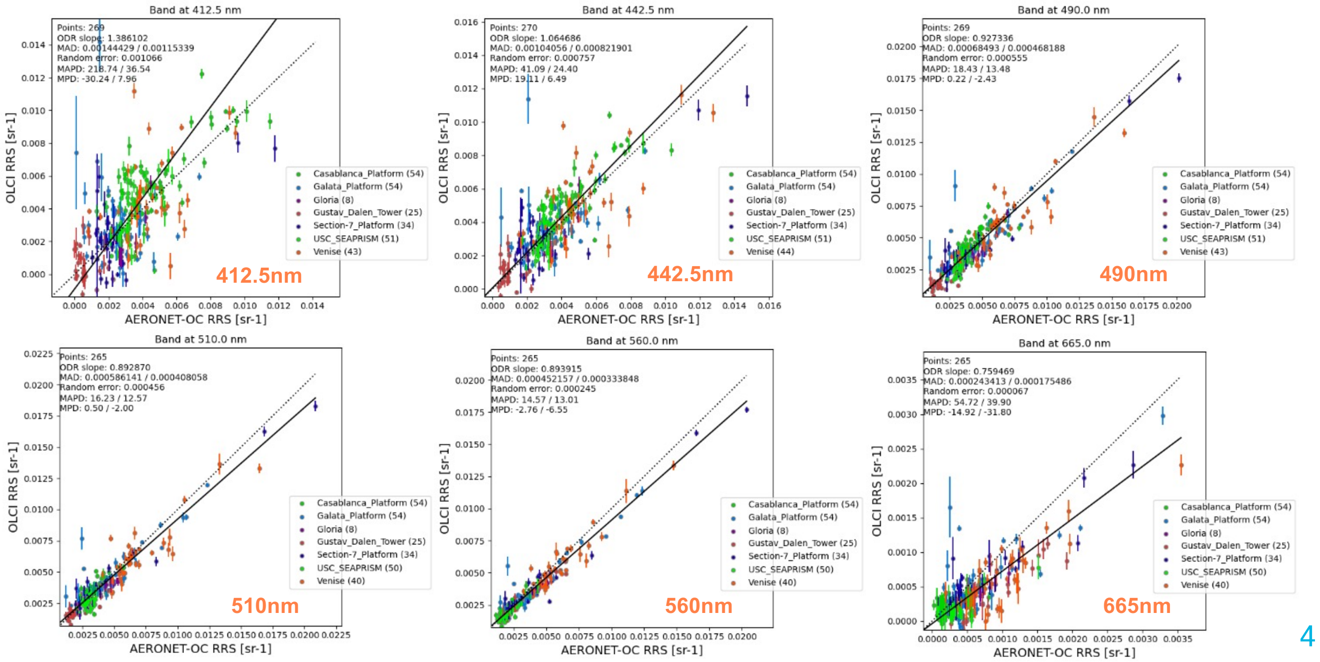
OLCI-B previous status

- 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-B

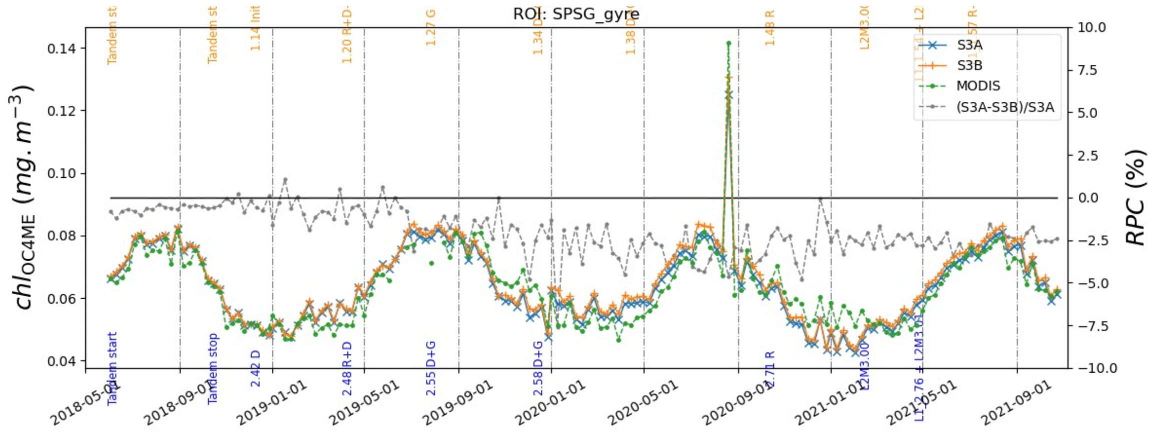


Sentinel-3 OLCI L2 Collection-3 chlorophyll mission inter-comparisons

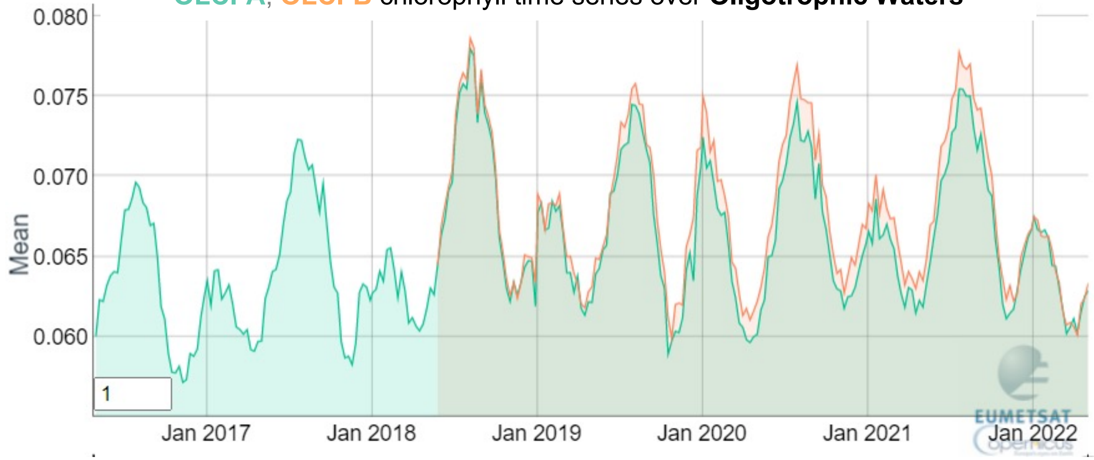
icus.eumetsat.int

t.int/media/47794

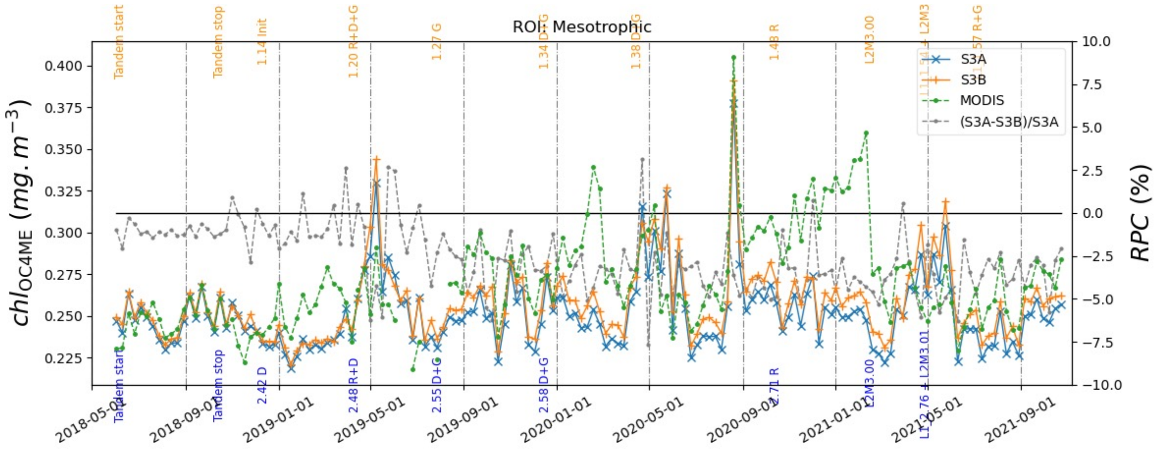
OLCI-A, **OLCI-B**, **MODIS-A** chlorophyll time series over the **South Pacific Gyre**



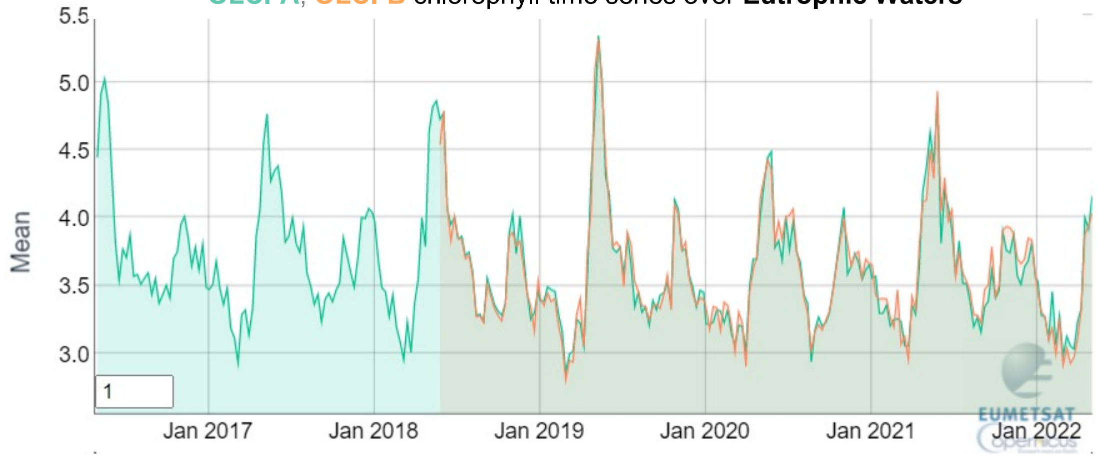
OLCI-A, **OLCI-B** chlorophyll time series over **Oligotrophic Waters**



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

- OLCI-A, OLCI-B, MODIS-A: only matching bins between sensors
- OLCI-A, OLCI-B: complete time series (non-overlapping bins)

Acknowledgements to NASA for MODIS-A products

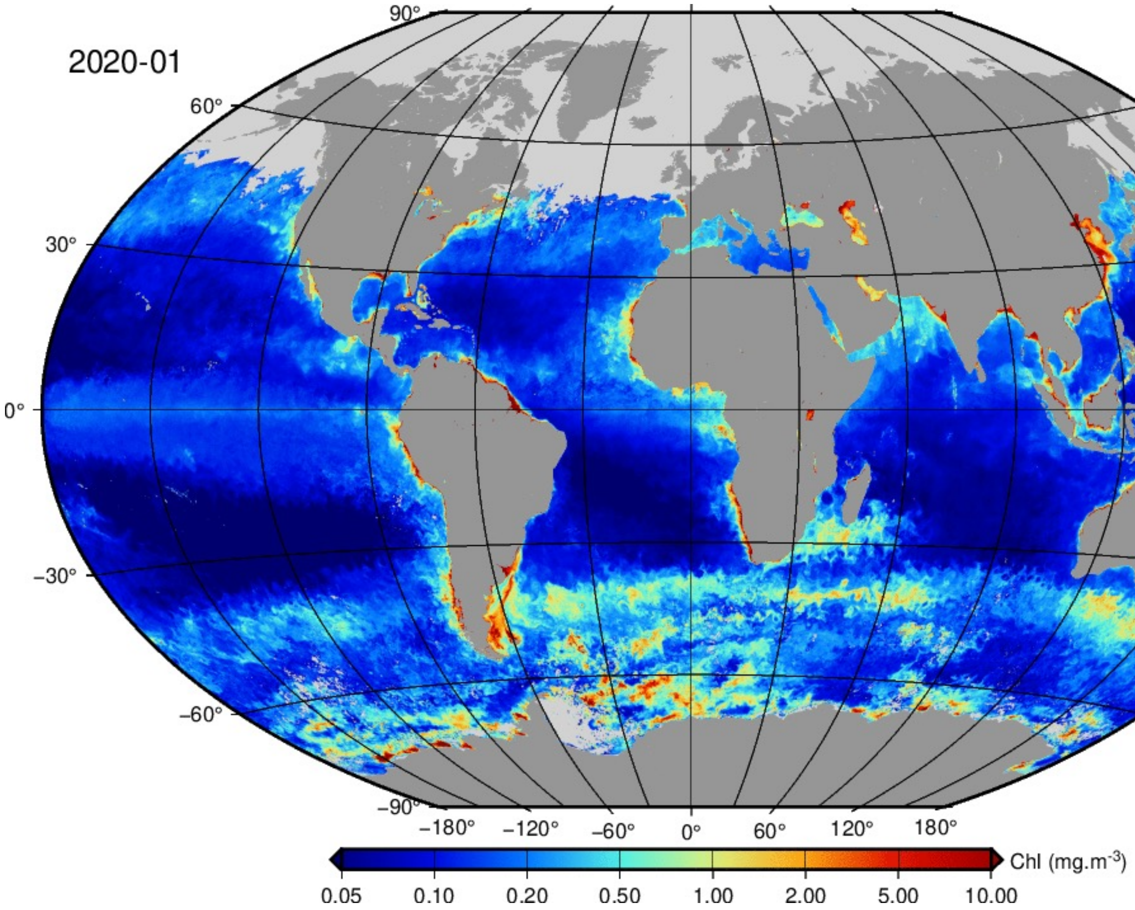
- Oligotrophic waters: chl < 0.1 mg/m³
- Mesotrophic waters: 0.1 ≤ chl < 1 mg/m³
- Eutrophic waters: chl ≥ 1 mg/m³

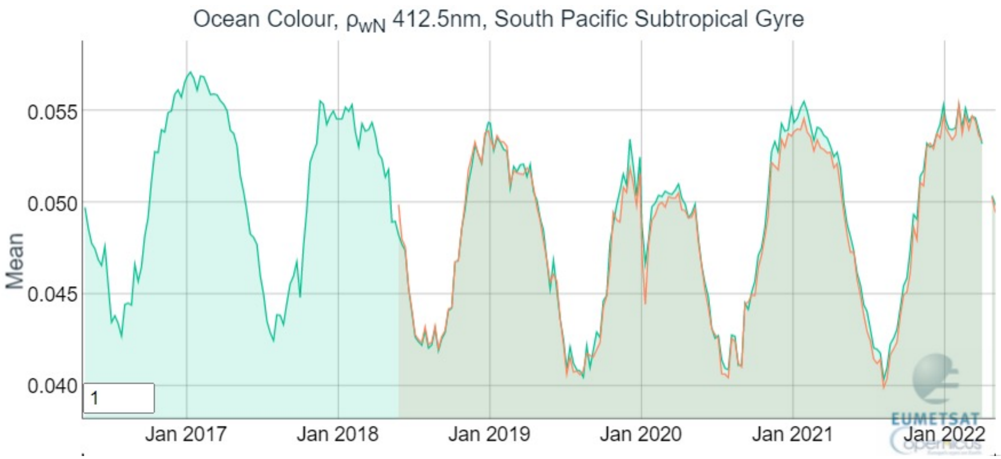
Collection-3 status

- **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

METIS-OC

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

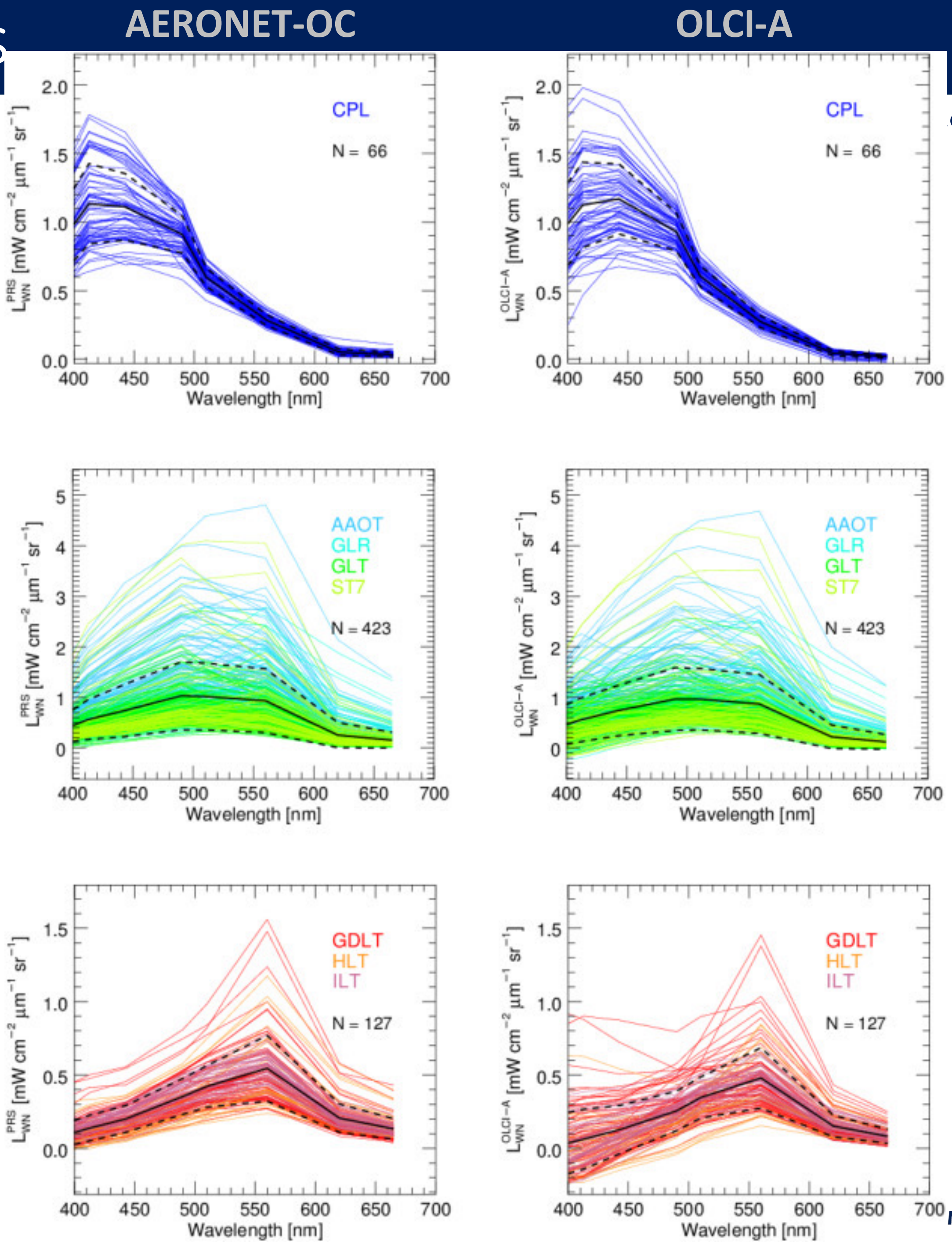




OLCI Collection-3 validation papers

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



Clear oligotrophic and mesotrophic waters

Generic complex waters with moderate concentrations of sediments and CDOM

High CDOM concentration waters

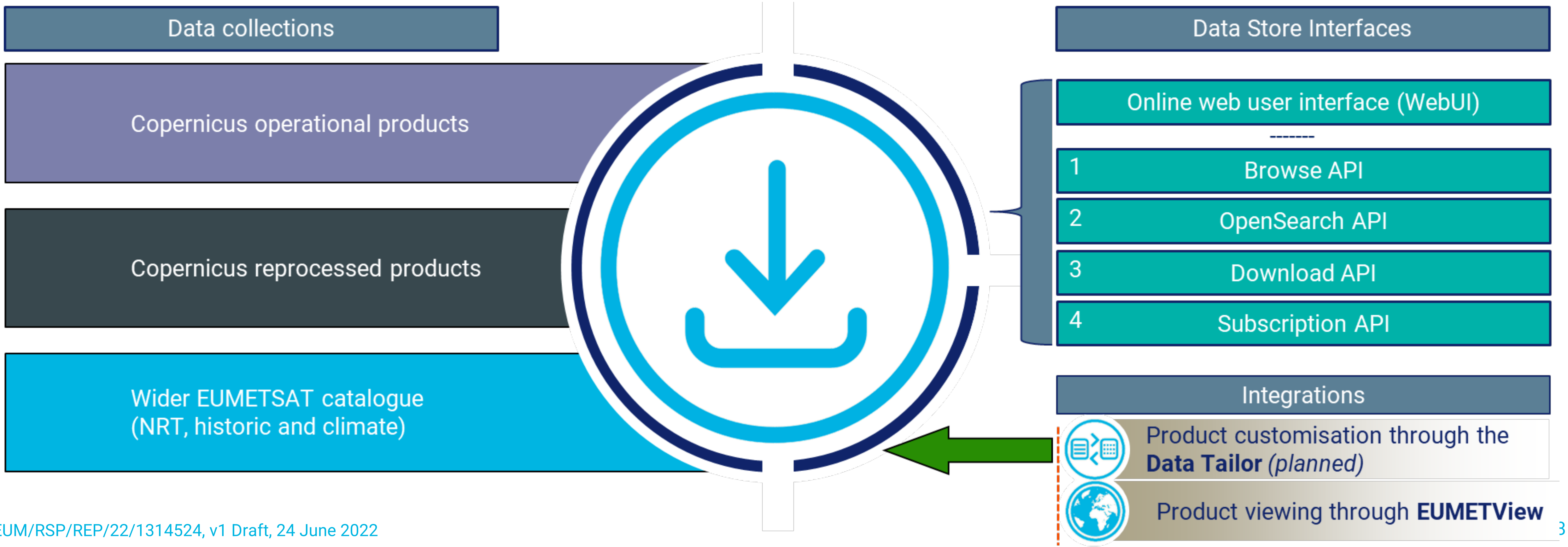
Curtesy Zibordi *et al.*, 2022

EUMETSAT Data Store – OLCI Collection-3 operational + reprocessed data

copernicus.eumetsat.int
https://data.eumetsat.int

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

- EUMETSAT Data Store: *https://data.eumetsat.int*
- Collection-3 reprocessed and operational data are available on EUMETSAT Data Store
- 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

copernicus.eumetsat.int

https://www.eumetsat.int/media/47794

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
- Implementation of new OLCI L2 products, IOP and Fluorescence
- Additional Ocean Colour algorithm evolutions, e.g. flags, chlorophyll product, optical water types

Ocean Colour processing 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

Improvement in Ocean Colour Standard Atmospheric Correction (OC-SAC)

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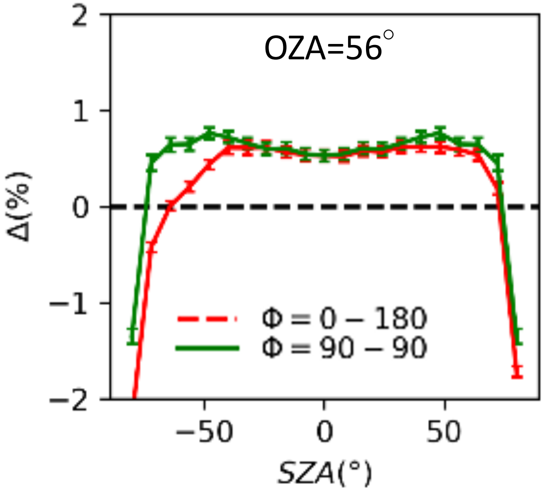
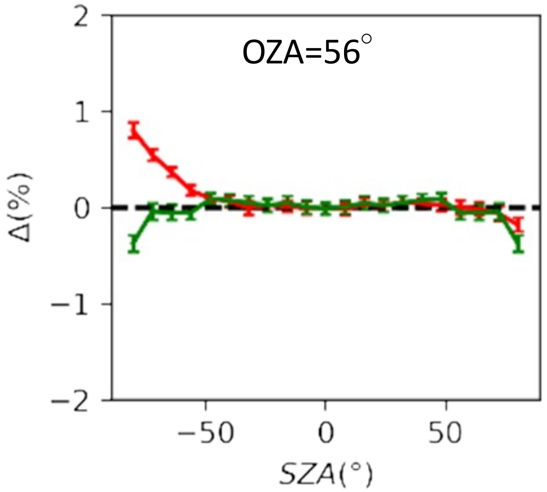
https://www.eumetsat.int/oc-sac

OC-SAC key new elements

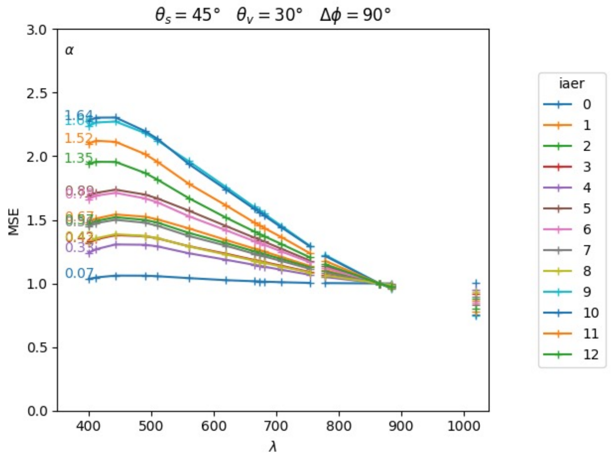
- Radiative Transfer Modelling at detector wavelength, no smile correction
- Atmosphere Spherical effect, mainly for the molecular Rayleigh scattering
- Aerosol vertical profile, through a rough estimate of aerosol layer height with O_2-absorption bands
- Aerosol standard models from Ahmad *et al.,* 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

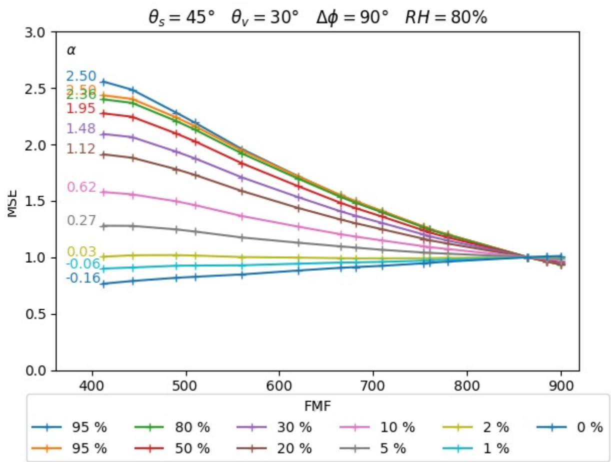
Plane Parallel → Spherical Shell modelling





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





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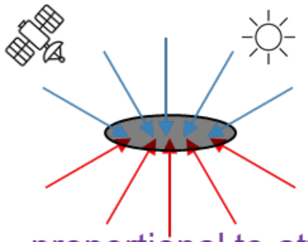
https://www.eumetsat.int/brdf-correction-s3-olci-water-reflectance-products

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

Æquora consulting, Consiglio Nazionale delle Ricerche, Institut de Ciències del Mar, solVo



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

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)

copernicus.eumetsat.int

https://www.eumetsat.int/S3-OLCI-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*
- Brockmann Consult 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*

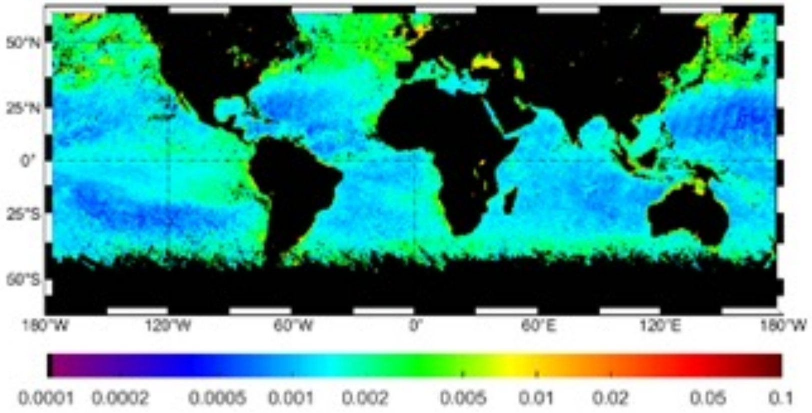
LOG LOV ACRI ST

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

IOP OLCI-A and OLCI-B RR time series is available from the 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

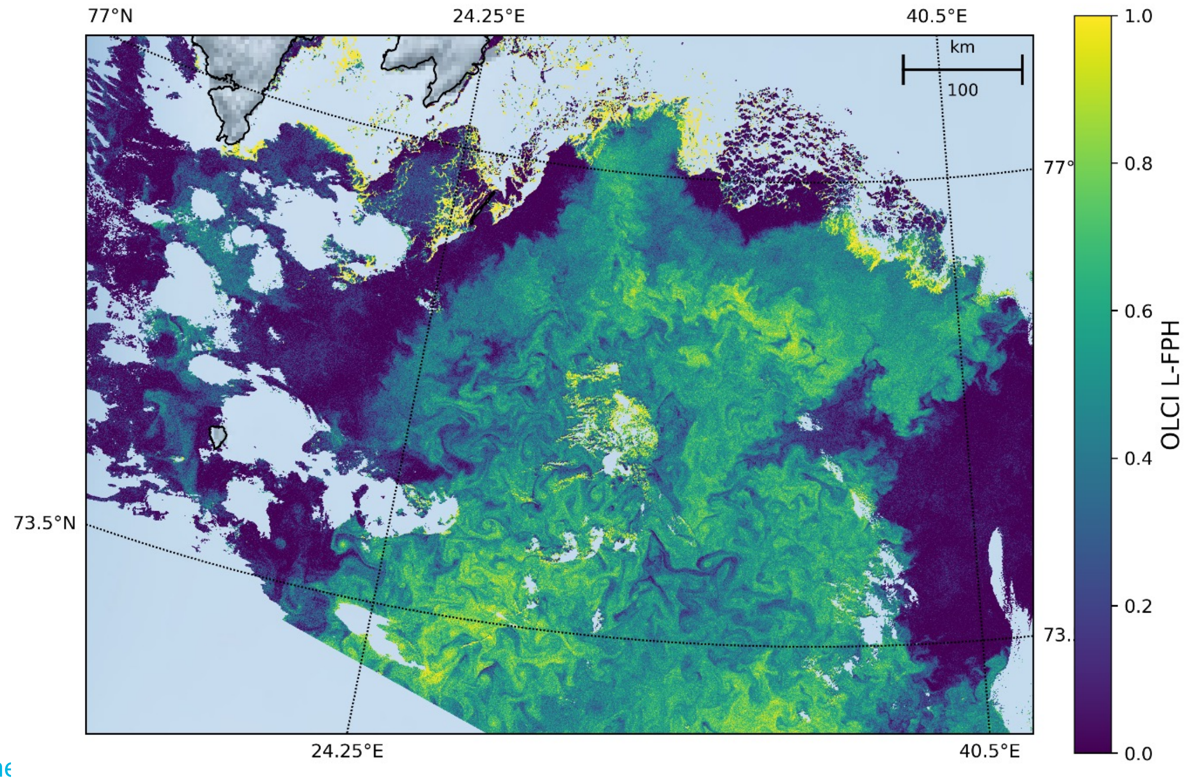
https://www.eumetsat.int/S3-OLCI-FLUO

OLCI Fluorescence test products

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

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]



Spectral Earth GmbH

Kritten *et al.*, 2020 RS MDPI Fluo

S3VT meeting – 18 - 20 October 2022 – ESA ESRIN

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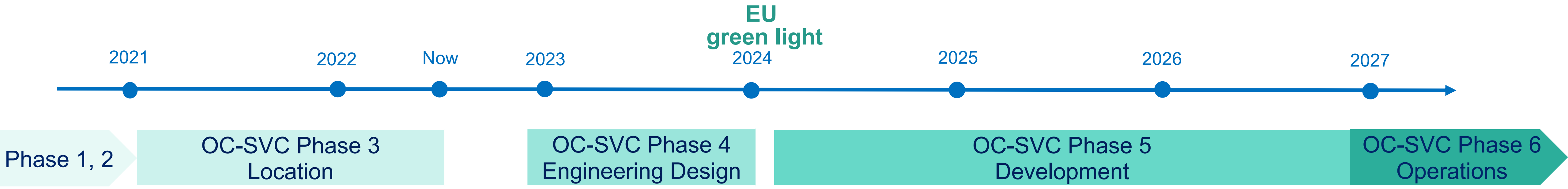
https://nikal.eventsair.com/7th-sentinel-3-vtm-2022/

Copernicus Ocean Colour System Vicarious Calibration (OC-SVC) roadmap

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

EUMETSAT manages OC-SVC infrastructure development activities for the Copernicus Programme on behalf of the European Commission

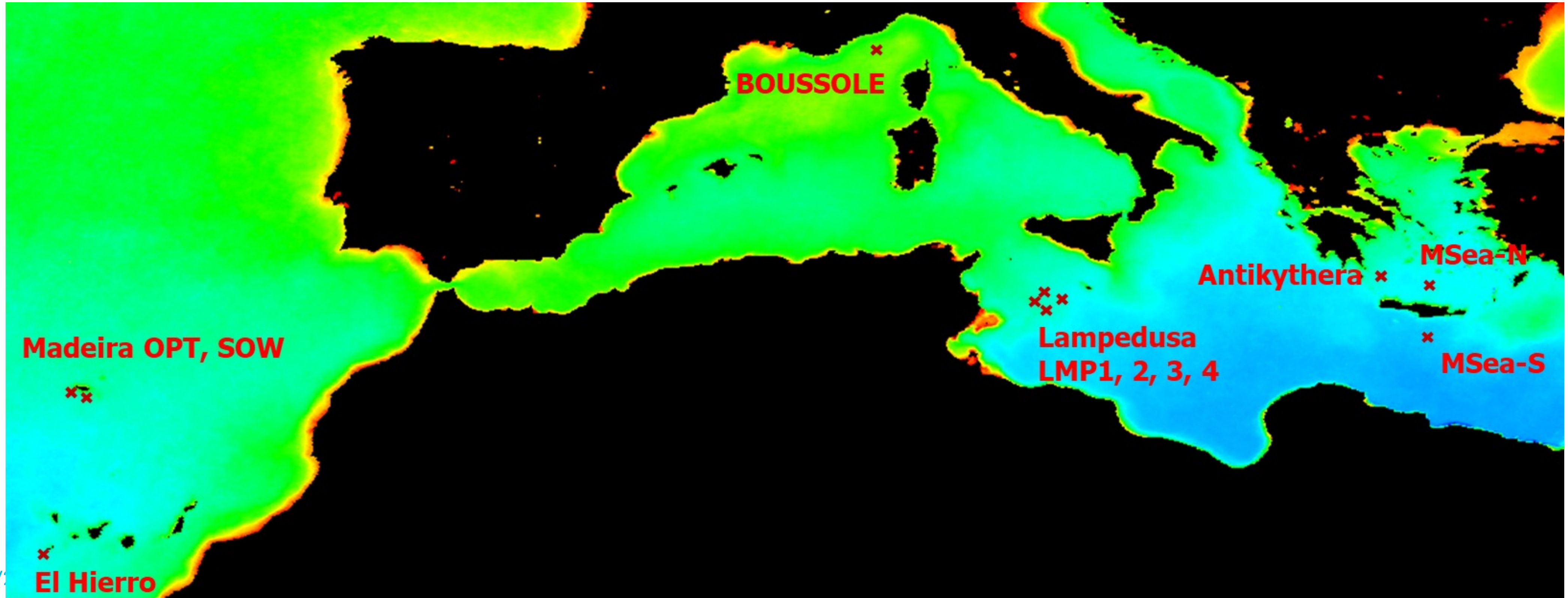
1. Requirements ✓
2. Preliminary Design, Project Plan and Costing ✓
3. Infrastructure Location ←
4. Engineering Design, Technical Definition, Specifications
5. Development, Testing and Demonstration in the Field
6. Operations



Copernicus OC-SVC infrastructure candidate locations

Five candidate locations for the Copernicus Ocean Colour System Vicarious Calibration infrastructure

- BOUSSOLE: 43.366N, 7.9E (investigated by LOV/IMEV/ACRI-ST)
- Crete: MSEA-N: 35.74N, 25.07E; MSEA-S: 34N, 25E; Antikythera: 36.2N, 23.55E (investigated by HCMR/Crete Uni.)
- El Hierro: 27.5876N, 18.1573W (investigated by IEO/AEMET)
- Lampedusa: LMP1: 35.5N, 12.8E; LMP2: 35.75N, 12.35E; LMP3: 35.85N, 12.73E; LMP4: 35.78N, 13.07E (investigated by CNR/ENEA)
- Madeira: SOW: 32.25N, 17W; OPT: 32.62N, 17.27W (investigated by IPMA)



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

Goal is to achieve the state-of-the-art, autonomous and dependable Copernicus OC-SVC capability for the coming 20+ years of the Copernicus Programme, including the Next Generation and Expansion missions

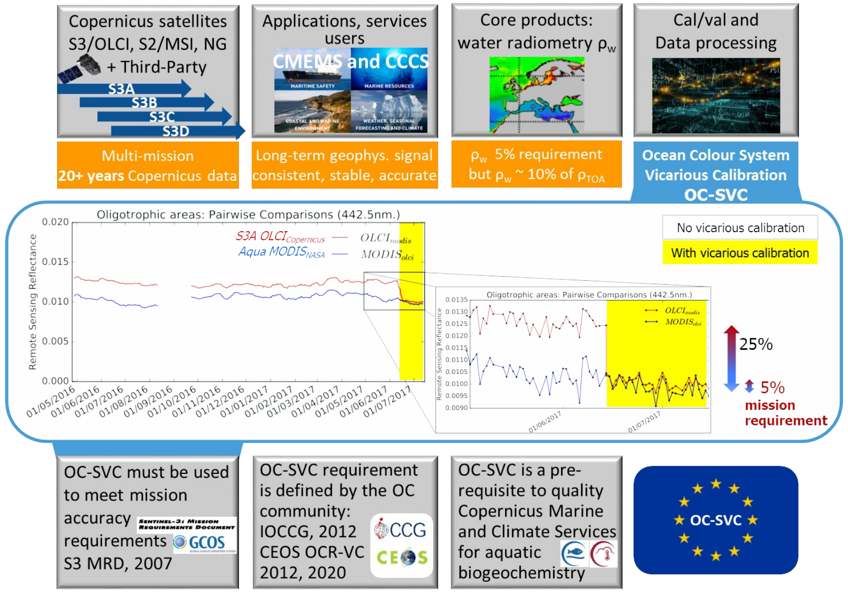
Review process is supported by an international Expert Review Board

Foundations for the review

- must be based on solid scientific evidence
  - must support the highest quality operational Ocean Colour observations and data services from the Copernicus Programme and international missions
  - must be driven by the uncertainty budget of the complete OC-SVC process
- must ensure value for money for the Copernicus Programme
- firstly, focus on mandatory selection criteria
- prioritise two sites in order to have a backup

Types of criteria

- potential of a location for OC-SVC high quality matchups with satellite missions
- marine and atmospheric criteria
- logistical and safety criteria
- location cost considerations



Analysed site characteristics and climatologies

Parameter	Selection criteria
OC-SVC matchup potential	– large numbers of matchups – matchups well spread throughout the four seasons of the year
cloud cover	– low, per season/month/day, high persistence of cloud free conditions – statistic: number of days per year where fractional cloud cover is > 0.1
chlorophyll concentration	– stable daily/monthly/seasonally and spatially homogeneous – statistic: Chl < 0.2 mg/m^3
radiometric variability	– low seasonal, diurnal and long-term variability in water spectra – statistic: optical range distributions: single peak dist., seasonal histograms
water bio-optical properties	– stable and spatially uniform IOPs, uniform within buoy depth
SST, salinity	– stable and spatially uniform
currents	– no major currents in the vicinity – low to minimise buoy tilt
waves, winds	– low wave height, no wave anomalies, low frequency of swells – low surface wind to minimise hydrosol advection, per season/month/day
aerosol optical thickness	– stable and spatially uniform – statistic: τ(550 nm) < 0.15
aerosol type	– only quantified and limited episodes of dust, biomass burning, pollution – statistical number of days per year of unfavourable aerosol outbreaks • dust: $\tau \geq 0.15$ and $\alpha \leq 0.5$ • biomass-burning and urban/industrial particles: $\tau \geq 0.1$ and $\alpha \geq 1.5$ • small urban-type aerosols: $\alpha > 1$
atmospheric gases	– quantified and limited absorbing gases: ozone, stratospheric and tropospheric NO_2 from cities and ship emissions), H_2O
prevailing marine/atmospheric circulation patterns	– mild marine and atmospheric conditions, including atmospheric pressure
solar illumination	– maximising light availability per season/month/day
logistics and existing supporting infrastructures	– distance from land optimised • to reach the clearest offshore waters and atmospheric conditions, and to avoid the adjacency effect from the land • to ensure easy ship journey and quick accessibility in case of emergency – nearby port, divers, workshops to support field maintenance operations – nearby facility to support storage, maintenance and calibration operations – existing supporting infrastructures are an advantage, e.g. atmospheric and marine observatories – availability of local qualified personnel is an advantage
communication links	– high volume data communication links between the water infrastructure and land, and the land, the 'Ground Segment' and the data dissemination point
bathymetry	– depth > 800 m, low sea floor slope
traffic	– minimal impact from maritime traffic – statistics: nearby shipping routes, and fishing and recreational traffic density
physical safety	– hurricanes / medicanes, statistics: frequency, intensity and trends – site protection in the field: placement on nautical charts, beacons etc.
seismic or volcanic activity	– none in the vicinity of the site or no impact on the site
costing	– not prohibitive and within the existing Routh Order of Magnitude costs

copernicus.eumetsat.int

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

Selected mandatory criteria

- potential of a location for OC-SVC high quality matchups with satellite missions
- cloud cover
- chlorophyll concentration, water reflectance
- aerosol optical thickness, aerosol type
- currents, waves and winds
- logistics and existing supporting infrastructures
- communication links
- bathymetry
- physical safety, traffic, hurricanes
- seismic or volcanic activity

Most fundamental criteria

1. potential of a location for OC-SVC high quality matchups with satellite missions
2. stable and clear water optical conditions
3. stable, clear and maritime atmospheric conditions
4. logistical readiness

Report in review, to be published in July 2022

Fiducial Reference Measurements for Satellite Ocean Colour (FRM4SOC-2)

copernicus.eumetsat.int

https://frm4soc2.eumetsat.int

FRM4SOC-2 overarching goal

- To ensure the adoption of FRM principles across the Ocean Colour (Water Quality, Aquatic Ecosystem…) community

FRM4SOC-2 developments to achieve the goal – a set of "cooking recipes" to make the adoption of FRM principles as simple as possible for the community

- Fully characterise the two most common Ocean Colour Radiometer classes (TriOS-RAMSES, Sea-Bird HyperOCR)
- Provide community guidelines on radiometer cal/char schedules
- Develop radiometer cal/char guidelines for laboratories (includes a lab exercise to test the guidelines and inter-compare results)
- Provide highly prescriptive and detailed FRM measurement procedures (following from the IOCCG protocols and FRM4SOC-1 experience)
- Develop community processor for in situ radiometric measurements (cooperating with NASA on HyperInSPACE)
- Develop a complete end-to-end uncertainty budget for the instruments and the measurements and include the uncertainty calculations in the community processor
- Review and test the developed procedures, guidelines and tools via a field experiment and a workshop with international participation

Universitas Tartuensis 1632 · ACRI ST · Brockmann Consult GmbH · NPL National Physical Laboratory · PML Plymouth Marine Laboratory · museum Royal Belgian Institute of Natural Sciences

FRM4SOC-2, Project Workshop – international participation very welcome!

https://frm4soc2.eumetsat.int

Geostationary ocean colour

copernicus.eumetsat.int

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

Broad interest in Ocean Colour geostationary products

- Emerging activity for EUMETSAT's Ocean and Sea Ice – Satellite Application Facility (OSI-SAF)
- Requirement from CMEMS OC-TAC

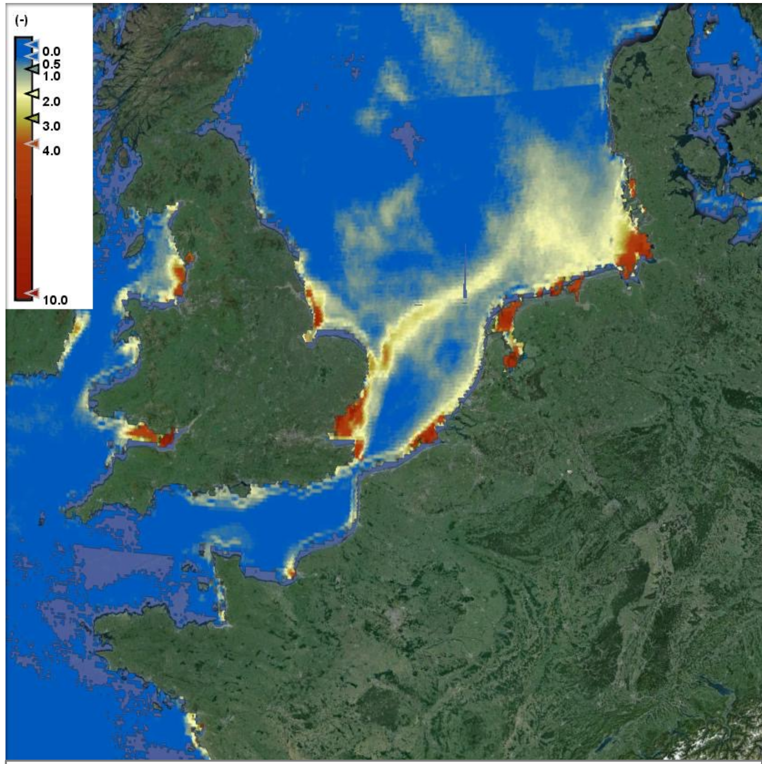
Building on initial EUMETSAT activities in 2015/16

- User Requirements analysis
- Prototype Processor development and validation

Development of extended geostationary capabilities from EUMETSAT's missions, starting Q4 2022

- Scientific and technical development of the Prototype Processor into the Day-2 Multi-Mission processor
- MSG-SEVIRI demonstration products: water turbidity time series
- MTG-FCI potential for additional and improved products, like chlorophyll

Geostationary test products in off-line processing for validation



MSG SEVIRI prototype geostationary water turbidity product
August 2008

East Anglian sediment plume

Summary

copernicus.eumetsat.int

https://www.eumetsat.int/ocean-colour-services

EUMETSAT's Ocean Colour L2 main development activities

- Ocean Colour operational processor improvements
- Copernicus System Vicarious Calibration (OC-SVC) infrastructure
- FRM4SOC-2 in situ radiometry
- Geostationary Ocean Colour from EUMETSAT's missions

Sentinel-3 OLCI L1 activities, not described

- e.g. lunar observations

Many of the activities match the IOCCG recommendations

- IOCCG/CEOS INSITU-OCR White Paper
- CEOS OCR-VC deliverable

OLCI-A and OLCI-B Moon observations per camera