Evolution of the CMEMS Ocean Colour global and regional products for Essential Ocean Variables during 2015-2021

V.E BRANDO

24/5/2022

→ THE EUROPEAN SPACE AGENCY

Evolution of the CMEMS Ocean Colour global and regional products for Essential Ocean Variables during 2015-2021

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1: CNR ISMAR, 2: ACRI, 3: PML, 4: HEREON, 5: AEQUORA,
6 SYKE, 7 :RBINS, 8 : Brockmann Consult, 9 : VITO

Copernicus Marine Service

OCTAC CMEMS

OCEAN COLOUR TAC — Copernicus Marine Service

The Ocean Colour TAC

The **OCTAC** operates the European Ocean Colour component within the **Copernicus Marine Service**, bridging the gap between space agencies and end-user with high-quality core ocean colour products for the **Global Ocean** and the **European regional seas** based on multiple Ocean Colour missions.

OCTAC provides in a timely and sustained manner a set of the Essential Ocean Variables (**EOVs**) that can be retrieved from **Ocean Colour** radiometry, i.e., **CHL, IOPs and PFTs/PSCs (**Phytoplankton Functional Groups and community structure).

Global and regional products are **higher level observational combined** products providing an **added value to standard products** delivered by the space agencies.

Regional products provide higher accuracy than standard global products as the **regionalisation of processing chains** takes into account the **bio-optical characteristics of each regional sea.**

Blended datasets are generated by applying the **appropriate algorithms across the open ocean and coastal waters.**

OCTAC – product evolution 2015-21 and Sentinel integration

Shift from **Science Missions** to **Operational Missions** carrying ocean colour sensors: **VIIRS** (on S-NPP and NOAA-20) and **OLCI** (on Sentinel 3 A &B)

In 2015, all NRT regional products were based on single sensors (MODIS and VIIRS), these datasets were replaced by **multi-sensor datasets** products leading to a significant **increase of the spatial coverage** of daily observations.

In May 2021, **OLCI datasets at 300m resolution** combining Sentinel-3 A and B, as well as the **Sentinel-2/MSI datasets at 100m**, were added to the catalogue.

The Ocean Colour TAC – product overview   (2021)

CMEMS Region	multi sensor 1km(Regions), 4km(GLO)				Sentinel-3 OLCI A+B 300m (Regions) 4km (GLO)				Sentinel-2 MSI A+B 100m			
	NRT		MY		NRT		MY		NRT		MY	
	L3	L4	L3	L4	L3	L4	L3	L4	L3	L4	L3	L4
Arctic Ocean	✓	✓	✓	✓	✓	✓			✓	✓		
NE Atlantic Ocean	✓	✓	✓	✓	✓	✓			✓*	✓*		
NE Atlantic Ocean		✓		✓								
Baltic Sea			✓	✓	✓	✓			✓	✓		
Black Sea	✓	✓	✓	✓	✓	✓			✓	✓		
Mediterranean Sea	✓	✓	✓	✓	✓	✓			✓	✓		
European seas	✓											
Global			✓	✓								
Global	✓	✓	✓	✓	✓							

Processing Levels:
L3: daily
L4: daily gap-filled and monthly averages

NRT: Near Real Time
MY: Multy Year reprocessed Time series

* the Sentinel-2 based products for the North Atlantic is produced over the IBI and NWS areas

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The Ocean Colour TAC – product overview   (2021)

Timeline (1997, 2016, 2020, 2021, 2022, 2023, 2024):
- MULTI 1km/4m MY → NRT
- S3/OLCI NRT
- S2/MSI NRT

NRT/MY continuity for each **MULTI** product line (**no MULTI NRT for BAL**)
Same chains for MULTI and S3/OLCI for each product line (**apart for GLO and BAL**)
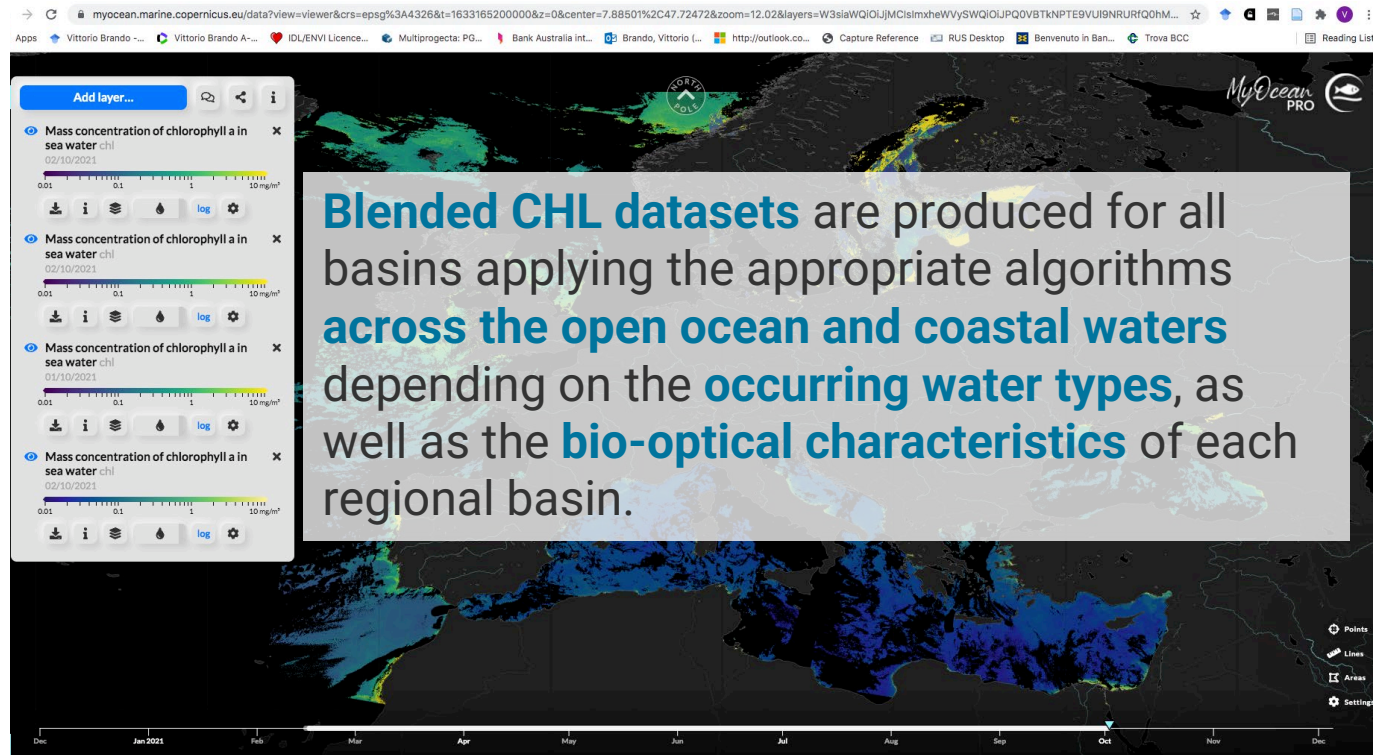No regional products for S2/MSI

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The Ocean Colour TAC – product overview   (2021)

MULTI at 1 Km /4 km
MY 1997-/30/6/2021,
NRT from 1/7/2021
Regional Seas 1 KM
Global 4 km

CHL

**Regionalisation of processing chains** takes into account the **bio-optical characteristics of each regional sea.**

Blended CHL datasets are produced for all basins applying the appropriate algorithms **across the open ocean and coastal waters** depending on the **occurring water types**, as well as the **bio-optical characteristics** of each regional basin.

The Ocean Colour TAC – product overview   (2021)

MULTI at 1 Km /4 km
MY 1997-/30/6/2021, NRT from 1/7/2021
Regional Seas 1 KM
Global 4 km

CHL

Regionalisation of processing chains takes into account the **bio-optical characteristics of each regional sea.**

Arctic
OC5CI (PML):
Case 1: CI (Hu et al. 2012)
Case 2: OC5 (Gohin et al. 2002)

Baltic Sea
MLP ensemble (Brando et al., 2021)

Atlantic Ocean
OC5CI (PML):
Case 1: CI (Hu et al. 2012)
Case 2: OC5 (Gohin et al. 2002)

Black Sea
Kajiyama et al., 2018:
Blend of Zibordi et al., 2015 (Case1) and Kajiyama et al., 2018 (Case2)

Global Ocean
Garnesson et al., 2019:
OC5 (Gohin et al. 2002) and CI (Hu et al. 2012)

Mediterranean Sea
Volpe et al. (2019):
Blend of MedOC (Case1) and Ad4 (Berthon &. Zibordi, 2004; Case 2)
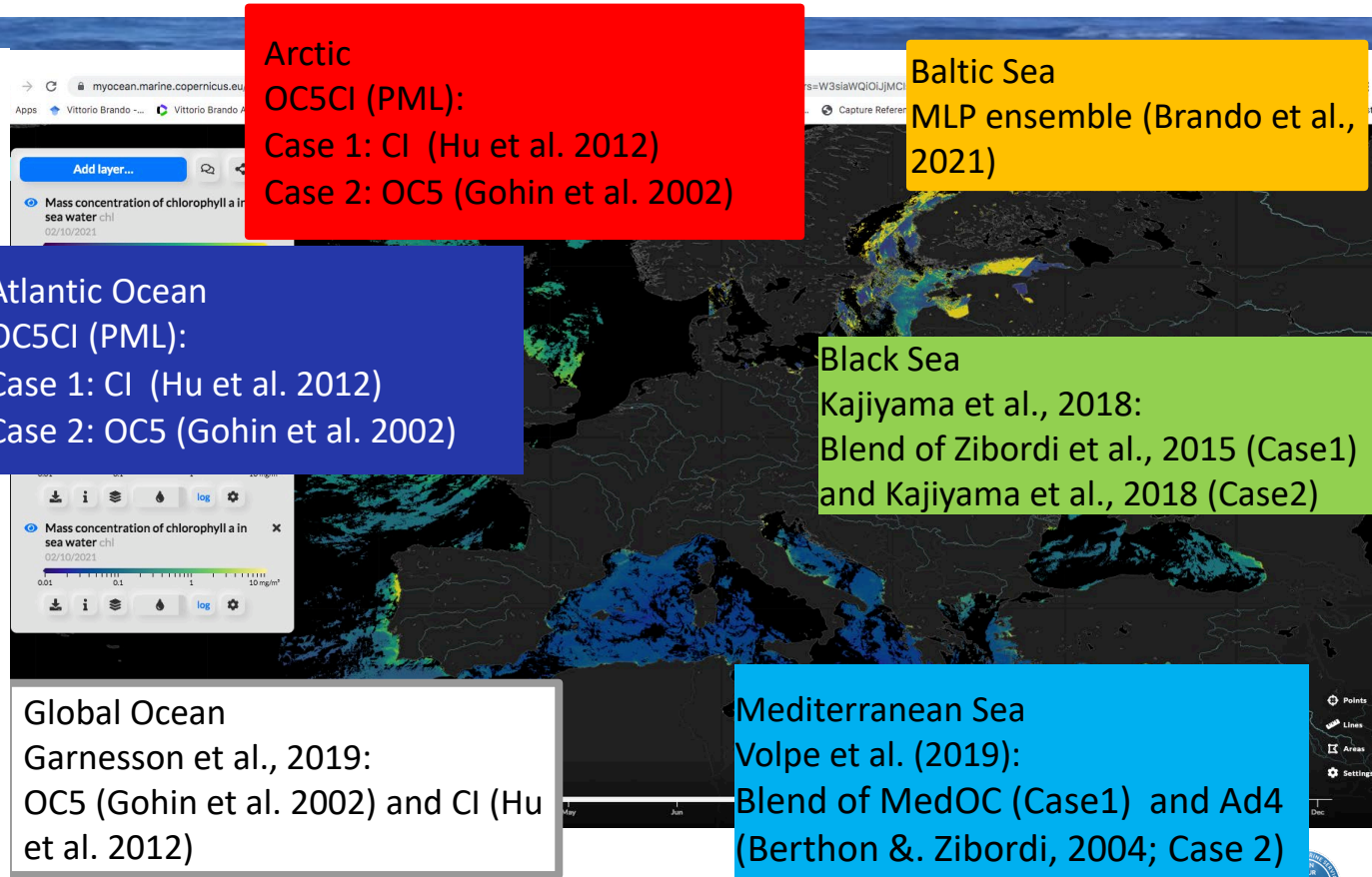
Product evolution: Mediterranean Sea – CHL algorithm
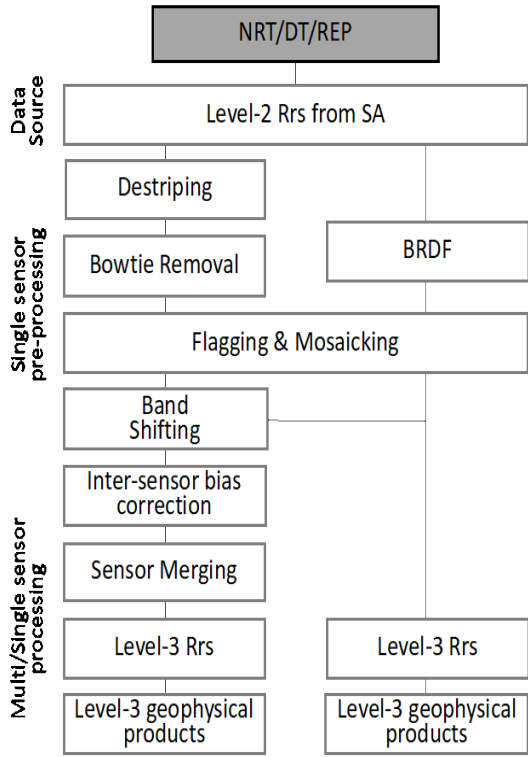
**Merging at common RRS wavelenghts
then CHL and Optics datasets are calculated with regional algorithms**

Merged Case 1 & Case 2 CHL algorithm: MedOC4+AdOC4

Case 1 [%]
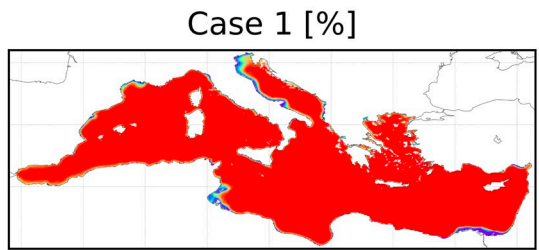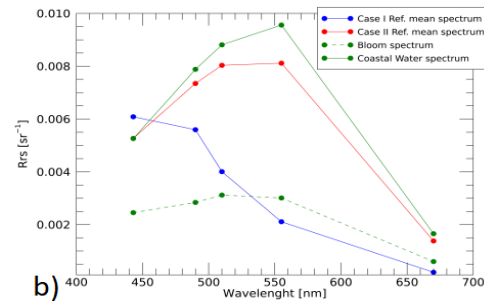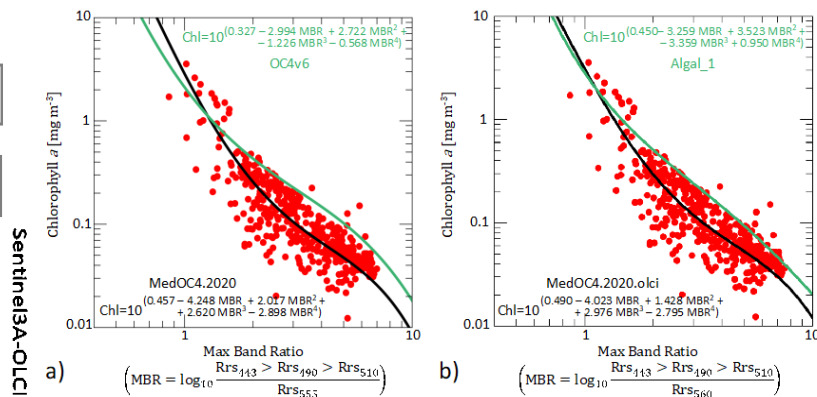
Overall a Blue waters basin!
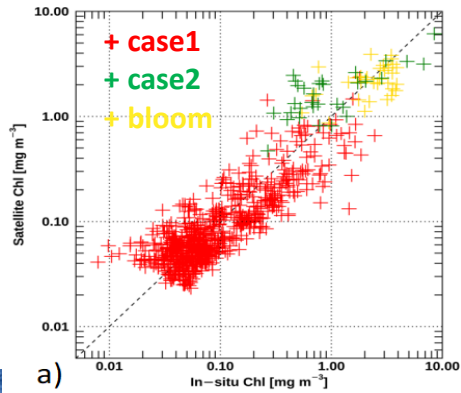
Product development in the Black Sea

Updated CHL algorithm for BS

1. merging of two different regional algorithms (i.e., a band-ratio (B/R) and a Multilayer Perceptron (MLP) neural net, accounting for optical complexity.
2. reducing the Chl-a overestimation of the B/R algorithm
3. broadening the range of applicability of the MLP neural net.

T. Kajiyama, D. D'Alimonte, and G. Zibordi. Algorithms merging for the determination of Chlorophyll-a concentration in the Black Sea. IEEE Geoscience and Remote Sensing Letters, 2018.
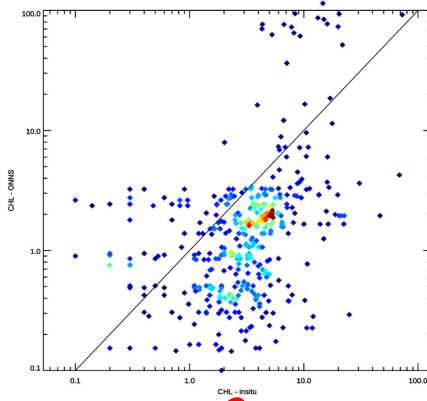

Chl-$\alpha_{B/R}$

Chl-α_{MLP}

Mixing function $f(h)$

RMSD = 0.32
bias = 0.024
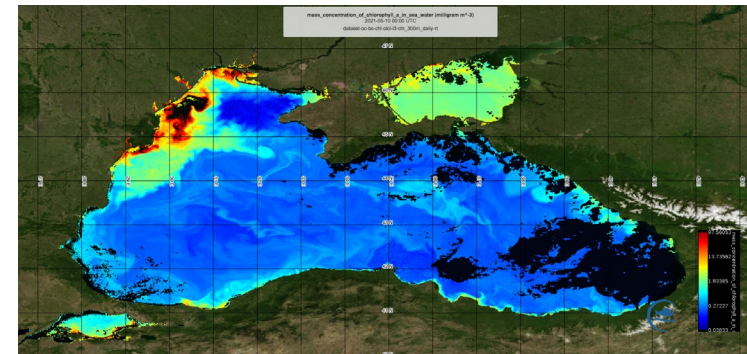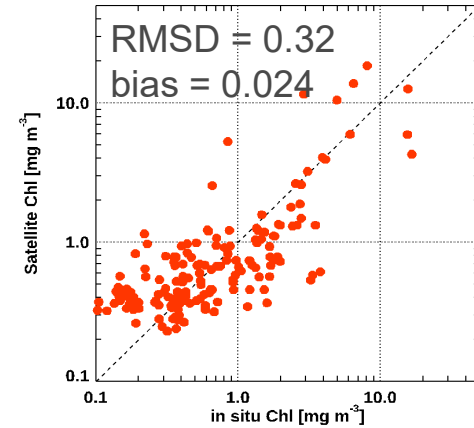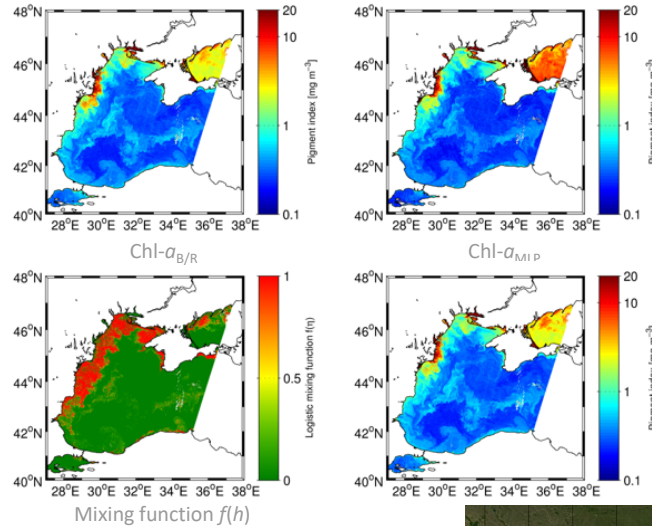
Product development in the Baltic Sea
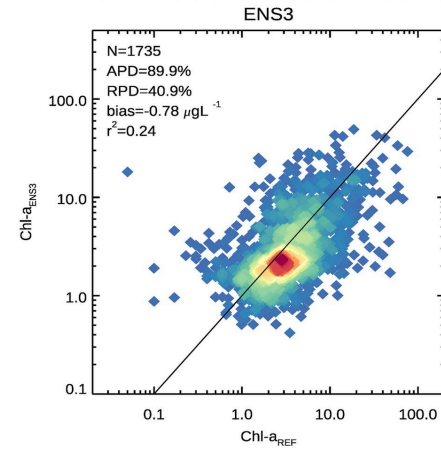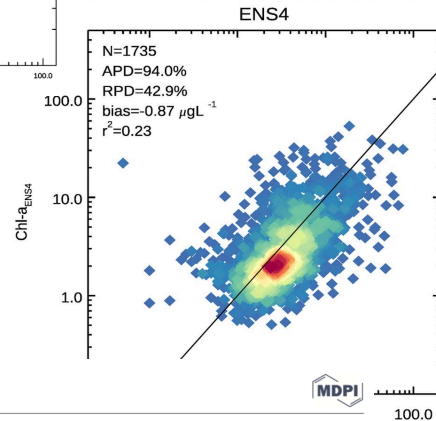
NRT: Sentinel 3A OLCI

1. Ad hoc L1 to L2 processing using C2RCC within SNAP but with improved nets
2. in-water processor **ONNS (OLCI Neural Network Swarm)** blended neural networks specialized for 13 different optical water classes

April 2019

MY: Multi-sensor

May 2021

Ensemble of Multilayer Perceptron (MLP) neural nets, accounting for optical complexity. (input OC-CCI R_{rs} values at 412, 443, 490, 510, 555 and 670 nm)

ENS4

N=1735
APD=94.0%
RPD=42.9%
bias=-0.87 μgL^{-1}
r^2=0.23

ENS3

N=1735
APD=89.9%
RPD=40.9%
bias=-0.78 μgL^{-1}
r^2=0.24

The OLCI Neural Network Swarm (ONNS): A Bio-Geo-Optical Algorithm for Open Ocean and Coastal Waters

Martin Hieronymi[1]*, Dagmar Müller[1†] and Roland Doerffer[1,2]

Phytoplankton Bloom Dynamics in the Baltic Sea Using a Consistently Reprocessed Time Series of Multi-Sensor Reflectance and Novel Chlorophyll-a Retrievals

Vittorio E. Brando[1,*], Michela Sammartino[1], Simone Colella[1], Marco Bracaglia[1], Annalisa Di Cicco[1], Davide D'Alimonte[2], Tamito Kajiyama[2], Seppo Kaitala[3] and Jenni Attila[3]
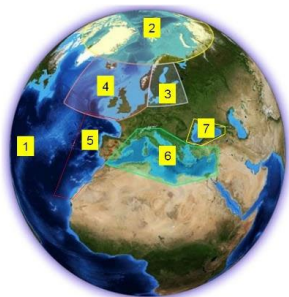
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The Ocean Colour TAC – product overview   (2021)
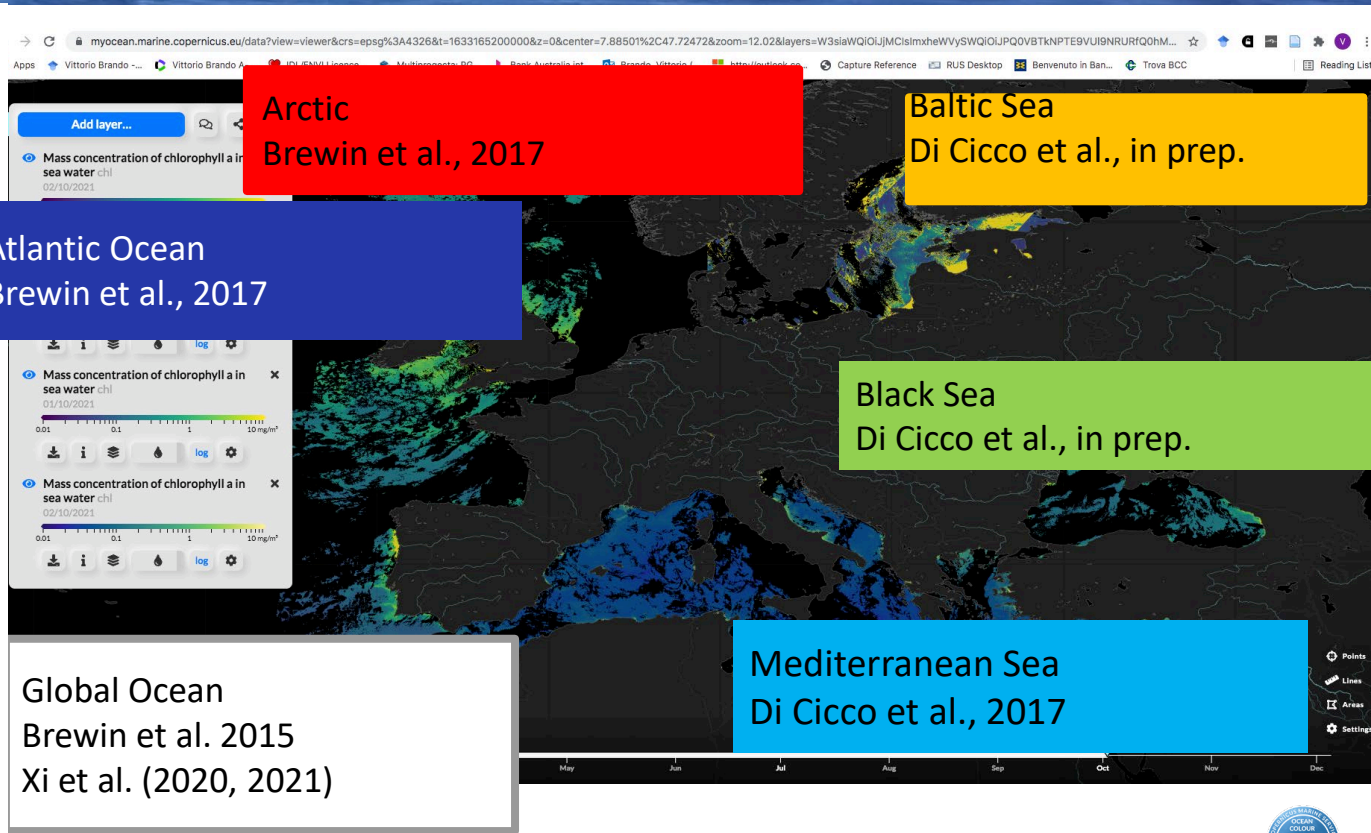
MULTI at 1 Km /4 km
MY 1997-/30/6/2021
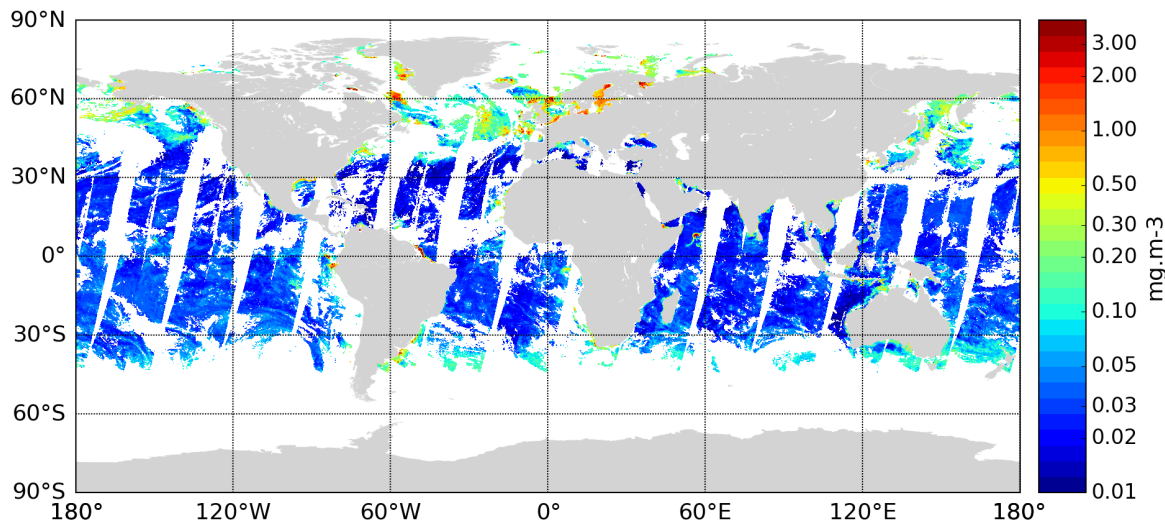
Regional Seas 1 KM
Global 4 km

PFTs
PSCs

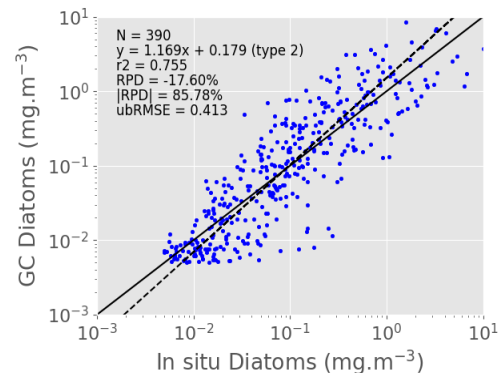**Regionalisation of processing chains** takes into account the **bio-optical characteristics of each regional sea.**

Arctic
Brewin et al., 2017

Baltic Sea
Di Cicco et al., in prep.

Atlantic Ocean
Brewin et al., 2017

Black Sea
Di Cicco et al., in prep.

Mediterranean Sea
Di Cicco et al., 2017

Global Ocean
Brewin et al. 2015
Xi et al. (2020, 2021)

Product evolution: Phytoplankton Functional Types

PFT + PSC for GLO: using OLCI-S3 and Multi sensor

*Daily diatoms concentration estimated by the merged product OLCI-S3A and OLCI-S3B for May 15th of 2019.*

(Xi et al., 2020, 2021)

July-2020: OLCI S3A NRT

Dec-2020: MODIS, VIIRS and MERIS for multi sensor NRT and REP
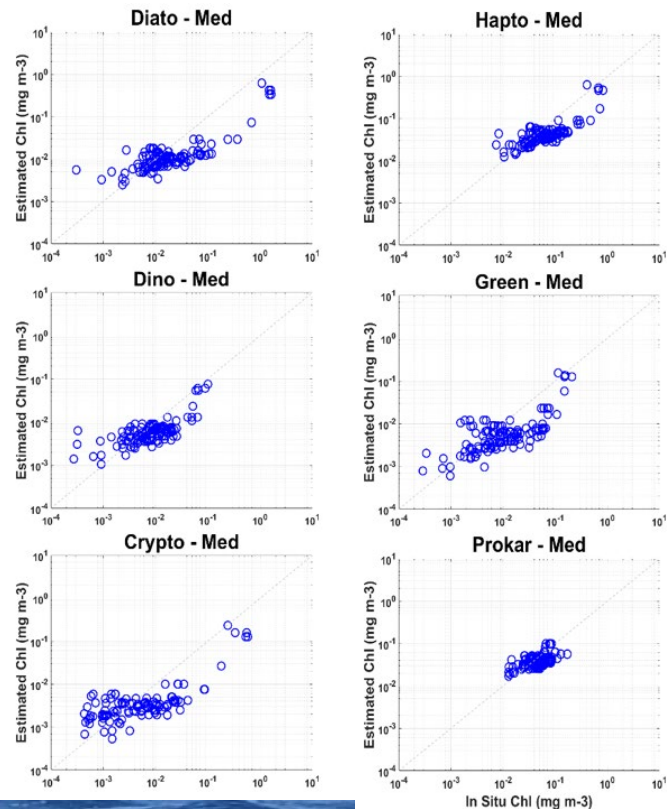
May 2021: uncertainty field

Product evolution: Phytoplankton Functional Types

Chlorophyll a concentration of Phytoplankton Functional Types

In situ :
diagnostic pigment data for the determination of the in-situ PFTs and PSCs come from a Mediterranean subset of the SeaBASS HPLC pigment in-situ dataset
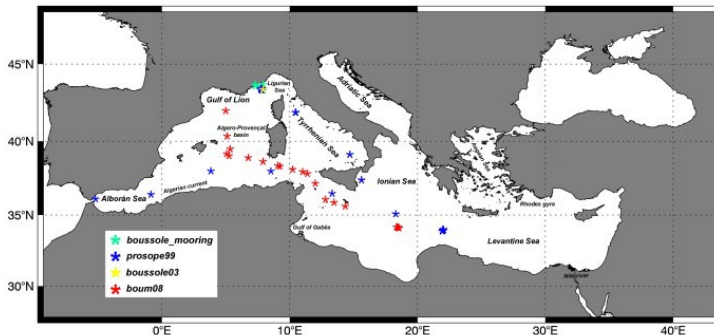
The global models underestimate most of the functional classes
Best performances of the regional algorithms for all the functional classes considered

Di Cicco et al., 2017

The Ocean Colour TAC – product overview   (2021)

CMEMS Region	multi sensor 1km(Regions), 4km(GLO)				Sentinel-3 OLCI A+B 300m (Regions) 4km (GLO)				Sentinel-2 MSI A+B 100m			
	NRT		MY		NRT		MY		NRT		MY	
	L3	L4	L3	L4	L3	L4	L3	L4	L3	L4	L3	L4
Arctic Ocean	✓	✓	✓	✓	✓	✓			✓	✓		
NE Atlantic Ocean	✓	✓	✓	✓	✓	✓			✓*	✓*		
NE Atlantic Ocean		✓		✓								
Baltic Sea			✓	✓	✓	✓			✓	✓		
Black Sea	✓	✓	✓	✓	✓	✓			✓	✓		
Mediterranean Sea	✓	✓	✓	✓	✓	✓			✓	✓		
European seas	✓											
Global			✓	✓								
Global	✓	✓	✓	✓	✓							

Processing Levels:
L3: daily
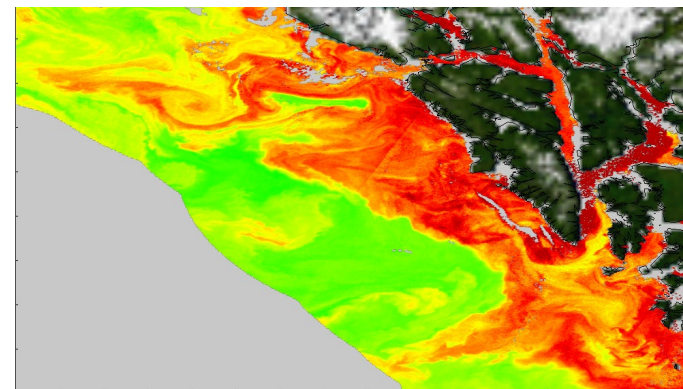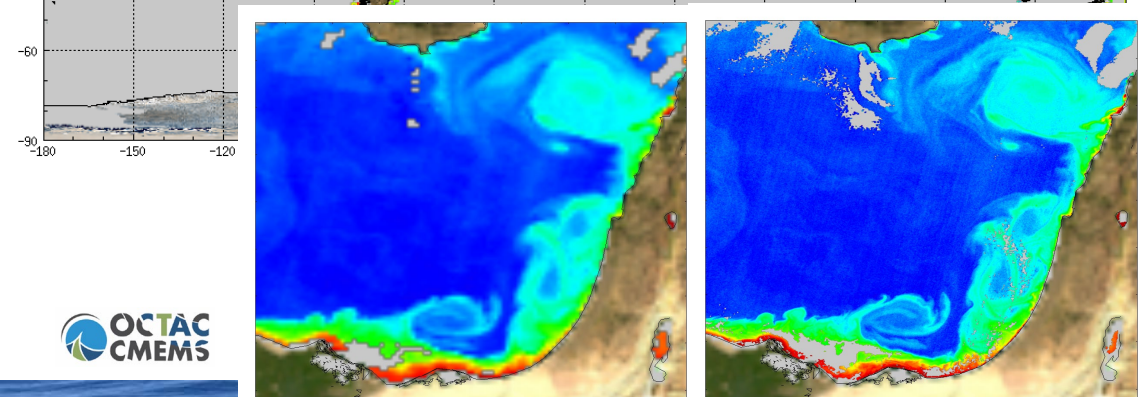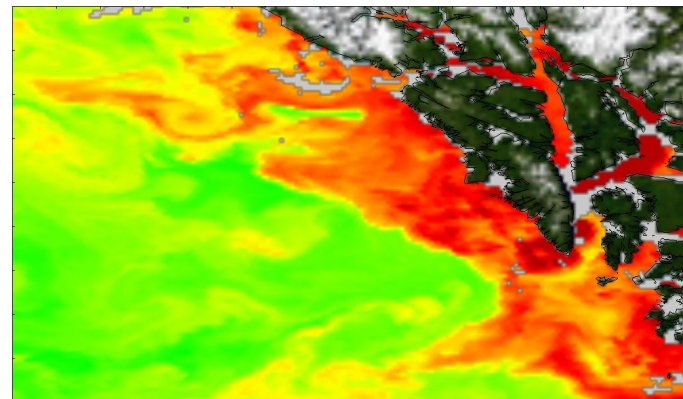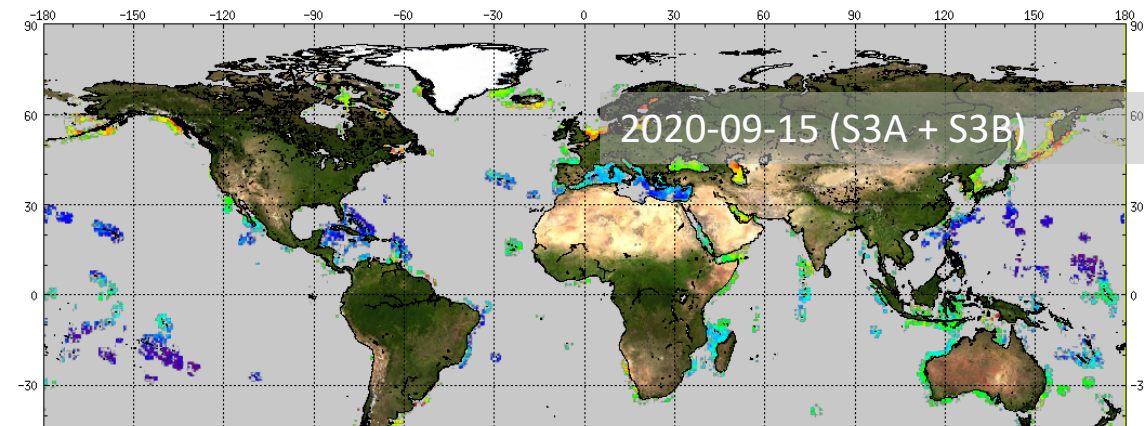**L4: daily gap-filled and monthly averages**

NRT: Near Real Time
MY: Multy Year reprocessed Time series

* the Sentinel-2 based products for the North Atlantic is produced over the IBI and NWS areas

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Product evolution: OLCI (S3A+B) L3 at 300m

From 2021-May release: from 4km to 300 meters, Global daily Chl (Coastal = 200km) S3A+S3B

2020-09-15 (S3A + S3B)

Product evolution: OLCI (S3A+B) L3 at 300m

OLCI single sensor (S3A+B) L3 at 300m for all Regional Seas
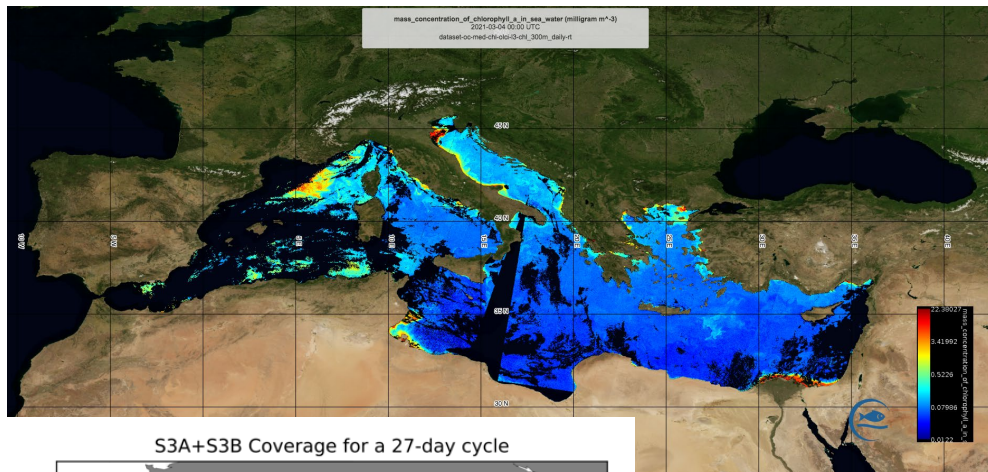
140° shift between S3A & S3B →
full daily coverage above ~40N
 - almost full for MED and ATL
 - full for ARC, BLK and BAL
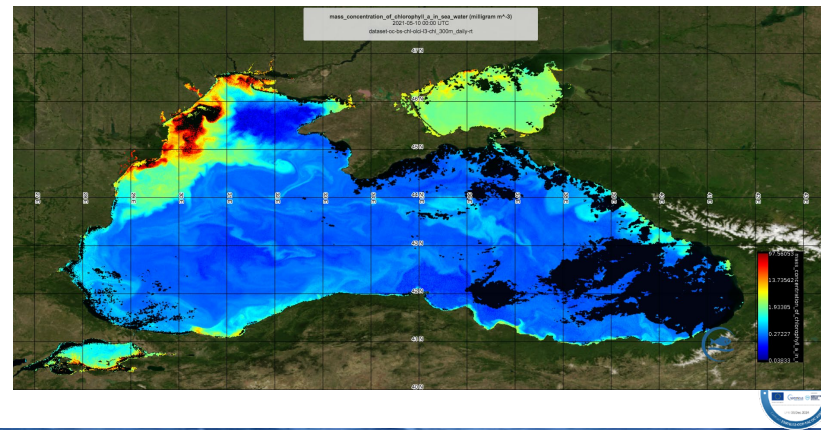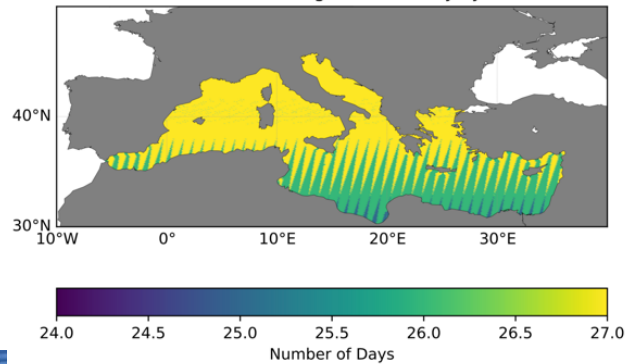
The Ocean Colour TAC – product overview   (2021)

OLCI (S3A+B) at 300m

NRT from 1/1/2021
Regional Seas
Global (Coastal = 200km)

CHL
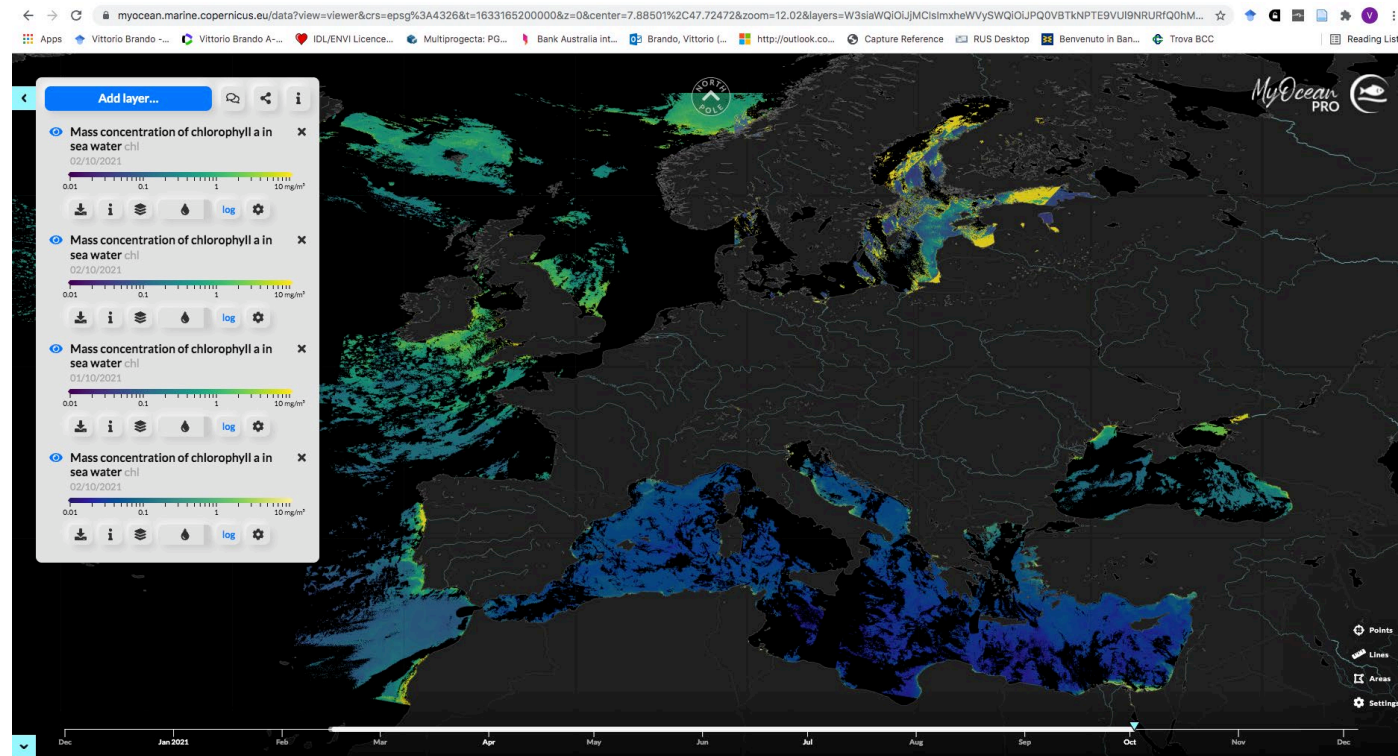
Regionalisation of processing chains takes into account the **bio-optical characteristics of each regional sea.**

The Ocean Colour TAC – product overview   (2021)

OLCI (S3A+B) at 300m

NRT from 1/1/2021
Regional Seas
Global (Coastal = 200km)

CHL

Regionalisation of processing chains takes into account the **bio-optical characteristics of each regional sea.**

Arctic
OC5CI (PML):
Case 1: CI (Hu et al. 2012)
Case 2: OC5 (Gohin et al. 2002)

Baltic Sea
OLCI Neural Network Swarm
(Hieronymi et al., 2015)

Atlantic Ocean
OC5CI (PML):
Case 1: CI (Hu et al. 2012)
Case 2: OC5 (Gohin et al. 2002)

Black Sea
Zibordi et al., 2015 (Case1)
    +Kajiyama et al., 2018 (Case2)

Global Ocean
OLCI: CI+OC4 (EUMETSAT)

Mediterranean Sea
Volpe et al. (2019):
Blend of MedOC (Case1) and Ad4
(Berthon &. Zibordi, 2004; Case 2)

The Ocean Colour TAC – product overview   (2021)

CMEMS Region	multi sensor 1km(Regions), 4km(GLO)				Sentinel-3 OLCI A+B 300m (Regions) 4km (GLO)				Sentinel-2 MSI A+B 100m			
	NRT		MY		NRT		MY		NRT		MY	
	L3	L4	L3	L4	L3	L4	L3	L4	L3	L4	L3	L4
Arctic Ocean	✓	✓	✓	✓	✓	✓			✓	✓		
NE Atlantic Ocean	✓	✓	✓	✓	✓	✓			✓*	✓*		
NE Atlantic Ocean			✓	✓								
Baltic Sea			✓	✓	✓	✓			✓	✓		
Black Sea	✓	✓	✓	✓	✓	✓			✓	✓		
Mediterranean Sea	✓	✓	✓	✓	✓	✓			✓	✓		
European seas	✓											
Global			✓	✓								
Global	✓	✓	✓	✓	✓							

Processing Levels:
L3: daily
L4: daily gap-filled and monthly averages

NRT: Near Real Time
MY: Multy Year reprocessed Time series

* the Sentinel-2 based products for the North Atlantic is produced over the IBI and NWS areas

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The Ocean Colour TAC – product overview   (2021)

Sentinel-2 MSI A+B 100m

**Coastal stripes of 20km for all European Seas**

- 100m spatial resolution
- Geographic lat/lon grid WGS84 (polar Lambertian Azimuthal Equal Area)
- L3: daily NRT;
- L4: daily DINEOF gap-filled monthly averages

Parameters

- Remote Sensing Reflectances - RRS(λ)
- Turbidity - TUR
- Suspended particulate matter – SPM
- Particulate Backscatter - BBP(λ)
- Chlorophyll Concentration – CHL (one algorithm for all European waters)

Production

- Cloud-based processing on CreoDias

Mass concentration of chlorophyll a in sea water chl
04/07/2021
0.01   0.1   1   10 mg/m³

L4: daily gap-filled
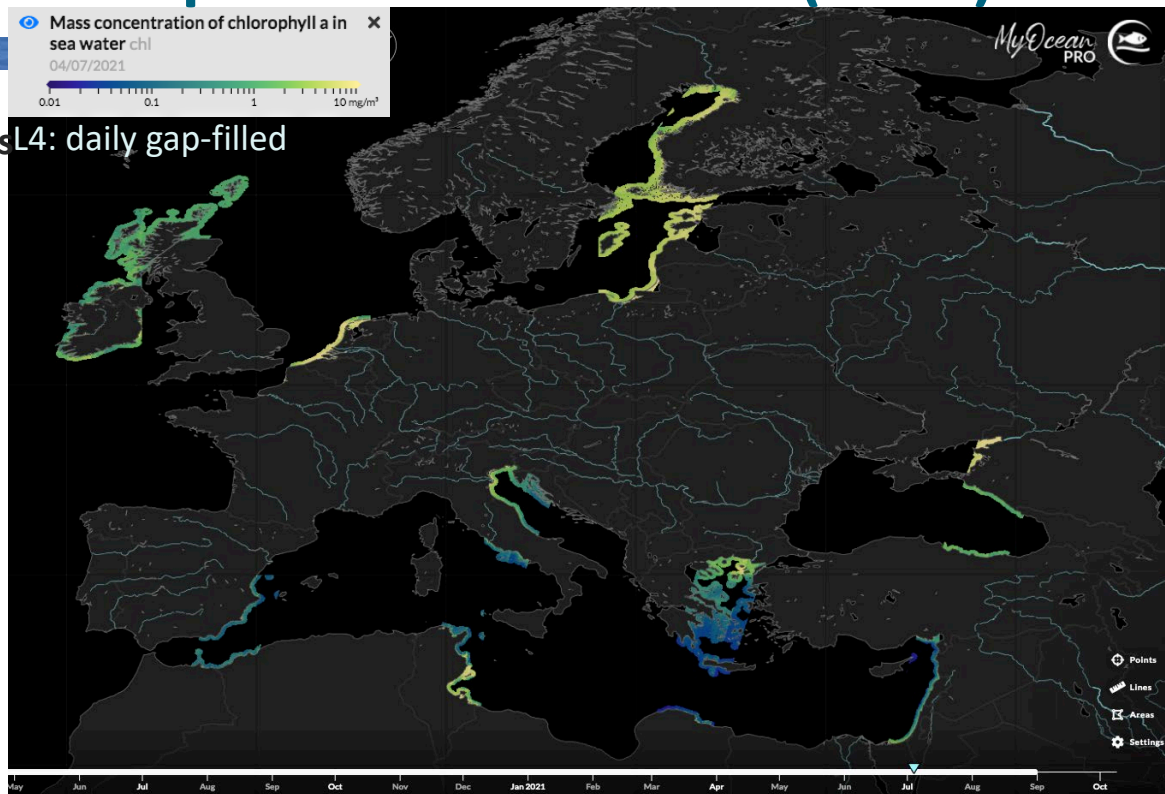
More details on next talk by Dimitry

The Ocean Colour TAC Catalogue evolution   2022

OCTAC catalogue reorganization for MULTI and S3/OLCI products　　　**July 2022**

OLD Product Numbers: **CHL**, **OPTICS**

CMEMS Region	multi sensor 1km(Regions), 4km(GLO)				Sentinel-3 OLCI A+B 300m (Regions) 4km (GLO)			
	NRT		MY		NRT		MY	
	L3	L4	L3	L4	L3	L4	L3	L4
GLO (ACRI)	032, 030	033, 083	085, 086	082, 081	032, 030	083	085, 086	082, 081
GLO (PML)			065, 064	093				
ATL (PML)	036, 034	090	067, 066	091	036, 034	090, 092		
ATL (ACRI)		037		098				
ARC	047, 046	087	069, 068	088	047, 046	087, 089		
BAL	-	-	080, 097		049, 048	332		
MED	040, 038	041, 039	073, 095	078	040, 038	041, 039		
BLK	044, 042	045, 043	071, 096	079	044, 042	045, 043		
EUR	050							

47 products
315 datasets

The Ocean Colour TAC Catalogue evolution 2022

OCTAC catalogue reorganization for MULTI and S3/OLCI products   July 2022

New Product names: OCEANCOLOUR_<Geographical Area>_BGC_<L3/L4>_<NRT/MY>_009_**1XX**

CMEMS Region	multi sensor 1km(Regions), 4km(GLO)				Sentinel-3 OLCI A+B 300m (Regions) 4km (GLO)			
	NRT		MY		NRT		MY	
	L3	L4	L3	L4	L3	L4	L3	L4
GLO (ACRI)	101	102	103	104	101	102	103	104
GLO (PML)			107	108				
ATL (PML)	111	112	113	114	111	112		
ATL (ACRI)		116		118				
ARC	121	122	123	124	121	122		
BAL	-	-	133		131	132		
MED	141	142	143	144	141	142		
BLK	151	152	153	154	151	152		
~~EUR~~	--							

25 products
119 datasets

Datasets	variables
plankton	CHL, PSCs, PFTs
pp	Primary production
reflectance	6 RRS bands for MULTI 11 RRS or more for OLCI
transp (for transparency)	KD, ZSD, SPM
optics	BBP, ATOT, ADG, APH, CDM

Data levels: _l3
_l4 (monthly averages)
_l4-gapfree (daily)

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Ocean Monitoring Indicators

Trends for 1997-2020 **of Chlorophyll** time series from the **MY** data

CMEMS Ocean Colour **regional M**Y datasets at **1 km** resolution
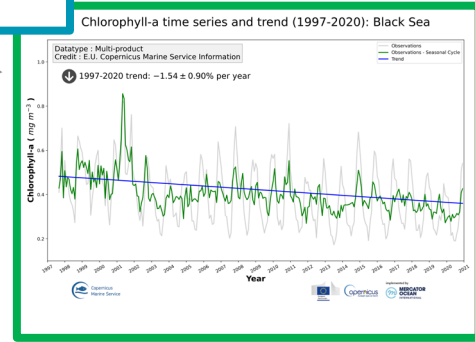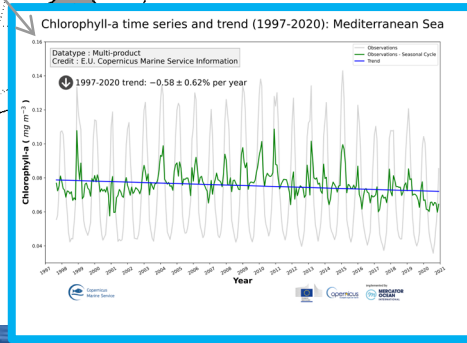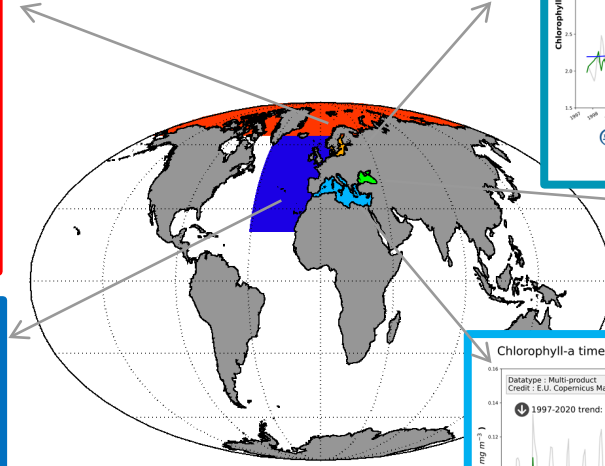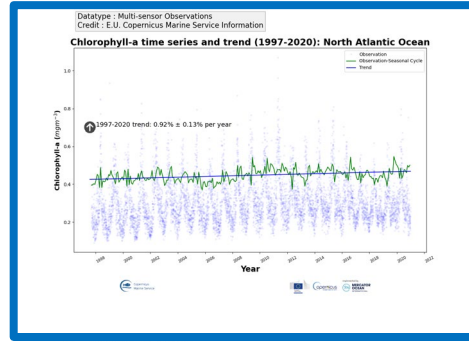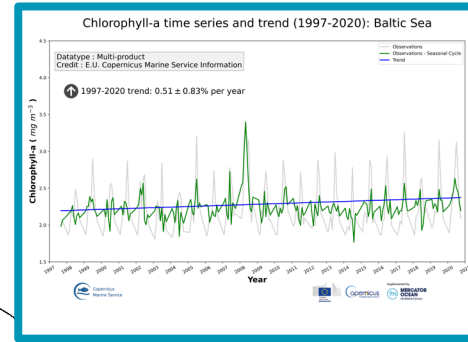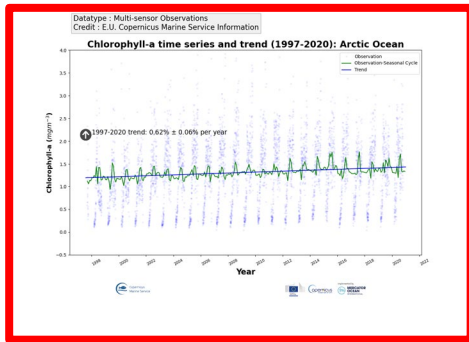
Ocean Monitoring Indicators

Potential eutrophication of European waters using satellite derived chlorophyll following the UN Sustainable Development Goal 14 framework

Potential eutrophic and oligotrophic areas in the European Seas derived for each year and basin using satellite-derived chlorophyll-a concentration from the corresponding CMEMS MY Ocean Colour datasets

A) This study

Sub-EEZ resolution for response to alert, if needed

Location of alert → Alert at location in consecutive year(s)? → If yes, increase level of alert

Daily, per-pixel Chl-a for reporting year

Number of days when Chl-a > baseline P90 for day

Daily, per-pixel baseline P90

Occurs >25% of days with valid observations in pixel in reporting year?

If yes

Pixels flagged as potentially eutrophic → Number of potentially eutrophic pixels per EEZ → Normalize to number of valid pixels per EEZ

Country EEZ Boundary

Potential Eutrophic Status for EEZ

Potential eutrophic and oligotrophic areas in the European Seas for the year 2020

Potential Oligotrophication
Potential Eutrophication
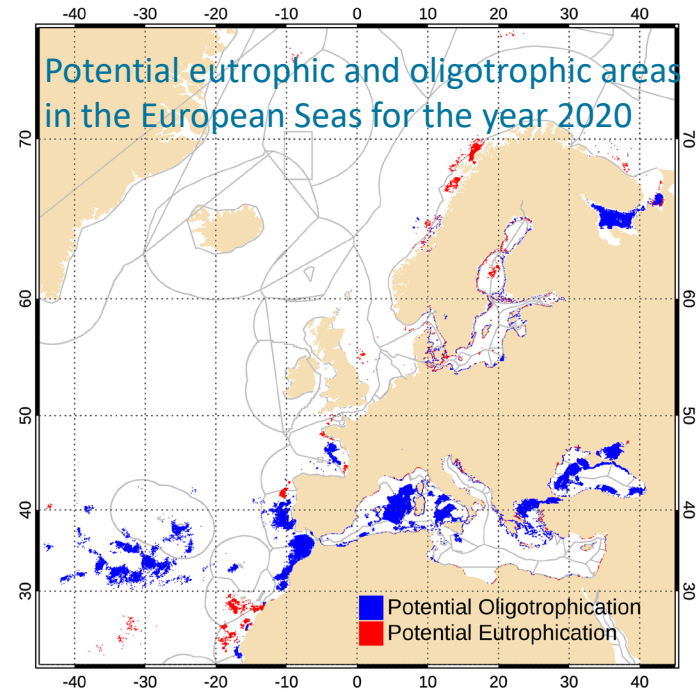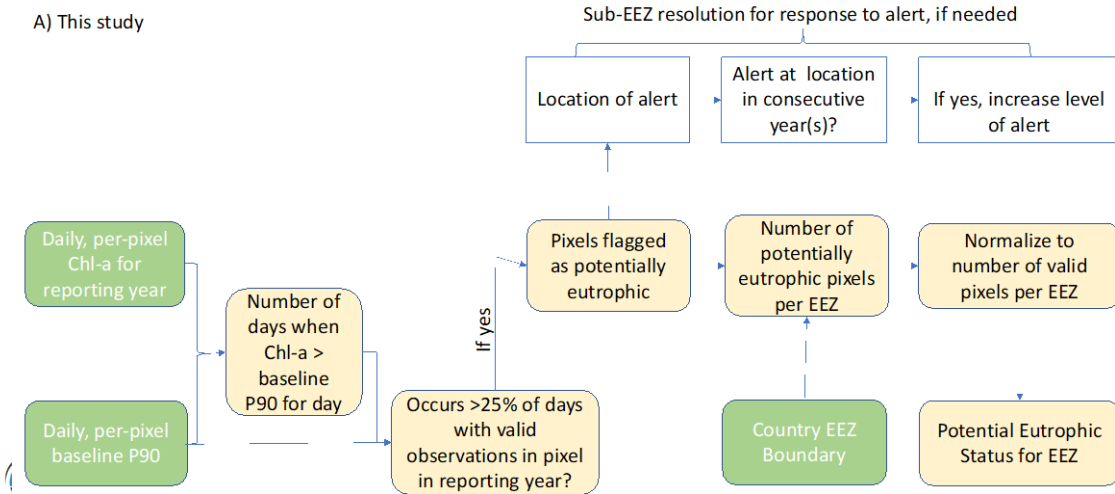
Brando et al., 2022 JOO OSR6 (in press)

Ocean Monitoring Indicators

Potential eutrophication of European waters using satellite derived chlorophyll following the UN Sustainable Development Goal 14 framework

Potential eutrophication maps were aggregated for each EEZ per year to derive the 1998-2020 time series for each European country of the Level 2 SDG 14.1.1a chlorophyll-a concentration sub indicator. Overall reduction in the Potential eutrophication in the second decade of the time series consistent with:

- findings by Friedland et al. (2021) based on ensemble analyses for all European seas.

- improvement from 2008 to 2017 in eutrophication status for the OSPAR Maritime Area (OSPAR ICG-EUT, 2017 and Gohin et al. ,2019)

- integrated annual classification of eutrophication status in the Baltic Sea, particularly in the last decade (Andersen 2017, EEA 2019ab).

SDG 14.1.1a L2 - CMEMS Regional algorithms

Brando et al., 2022 JOO OSR6 (in press)
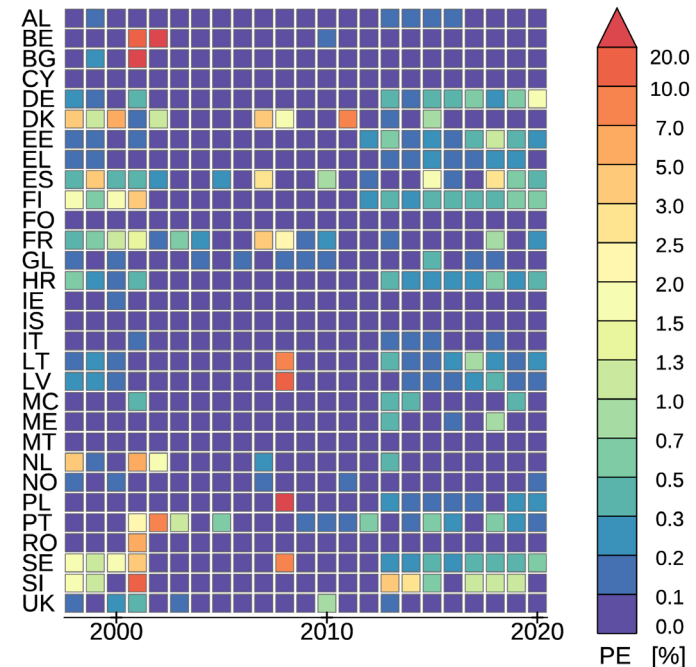
The Ocean Colour TAC Catalogue evolution   2022-24

✓ **Upstream missions:**
- ✓ **OLCI Global and Regional Reprocessing 2016-2022** (with EUM 3.0.1)
- ✓ Inclusion of **OLCI 3B** and **NOAA20** in NRT and MY **for GLO and all regional products**

✓ Updates in **Regional CHL and PFT/PSCs algorithms with a focus for complex waters**
- ✓ Update of **BAL OLCI NRT/MY processing chain** to be consistent with **MULTI MY**
- ✓ Addition of **PFT** for **MED, BAL, BLK** in NRT mode
- ✓ Addition of **PFT uncertainties** for **ATL, ARC and GLO** in MYP
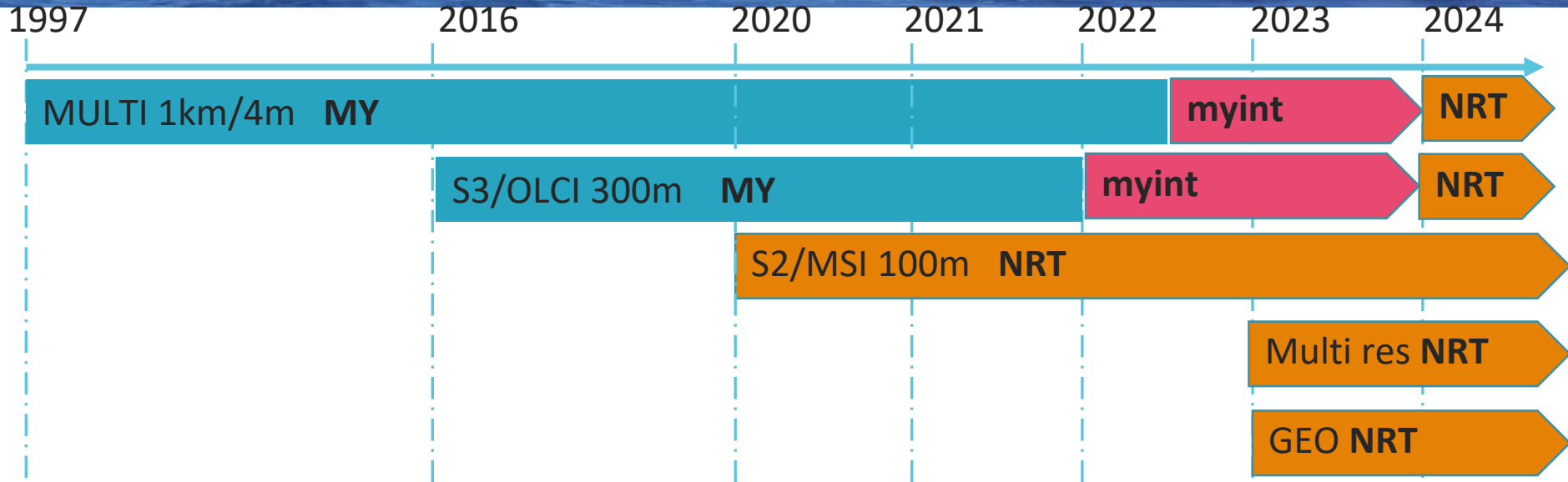
✓ **Primary Production:**
- ✓ **Accuracy improved for GLO** datasets
- ✓ **Regional PP** datasets in NRT and MY

✓ **S2 100m: CHL regional algorithms consistent** with **300m and 1 km** datasets

✓ **Synergy** between the **Geostationary** and existing CMEMS **multi sensor** products

✓ **Prototype of Multi-resolution products across 4 Km/1 km/300 m/100 m**

OCTAC CMEMS

The Ocean Colour TAC Catalogue evolution   2024

1997   2016   2020   2021   2022   2023   2024

MULTI 1km/4m MY → **myint** → **NRT**

S3/OLCI 300m MY → **myint** → **NRT**

S2/MSI 100m NRT

Multi res NRT

GEO NRT

NRT/MY continuity for each **MULTI** product line (**no MULTI NRT for BAL**)
NRT/MY continuity for each **S3/OLCI** product line
Same chains for MULTI and S3/OLCI for each product line (**apart for GLO**)
Same CHL blended algorithms for MULTI, S3/OLCI and **S2/MSI** for regional products

CMEMS

Thanks for your attention

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http://marine.copernicus.eu/ocean-colour-thematic-center-oc-tac/