Green Ocean TACs in CMEMS

- In Situ TAC
- Ocean Colour TAC
- Multi Observations TAC

The **Green Ocean** TACs provide **time series** for the Essential Ocean Variables (**EOVs**) related to **biogeochemistry** and the **carbon cycle** from:

- 1D in situ discrete data points
- 2D satellite fields and
- 1 to 3D integration with data fusion techniques

OUTLINE

Green Ocean TACs in CMEMS

- In Situ TAC
- Ocean Colour TAC
- Multi Observations TAC

TACs main achievements 2022-2024

- New upstream
- New product/variable
- Processing enhancement

Conclusion and perspectives

In Situ TAC a multi platform approach

Data at measurement points, i.e. discrete data (vertical profiles, trajectories)

Main green in situ parameters: chlorophyll-*a*, oxygen and nutrients (nitrate, silicate, phosphate) & carbonate system

- Each year, more in situ data to feed the products with new platforms *i.e. densification of the data within a region, for all parameters*

    Thanks to additional data providers (e.g. CTD and bottle data from ICES, historical research cruises) and through collaboration: with EMODnet, EuroGOOS and JERICO

Copernicus Marine Service

Development of the green in situ TAC portfolio

2016	2017	2018	2019	2020	2021	2022	2023	2024

Near real time regional multiparameter products include chlorophyll-a, oxygen, nutrients

QC upgrade for oxygen

QC upgrade for nutrients

QC upgrade for chlorophyll

Oxygen-Chlorophyll-a-Nutrients

Chlorophyll   Oxygen   Nutrients

Multiyear global biogeochemistry product

QC upgrade: river detection & removal of duplicates

QC upgrade with feedback from MFC

QC upgrade on vertical profiles

Carbon

Multiyear global carbon product

Updated of latest SOCAT and GLODAP datasets when available

Inclusion of some EMODnet chemistry data

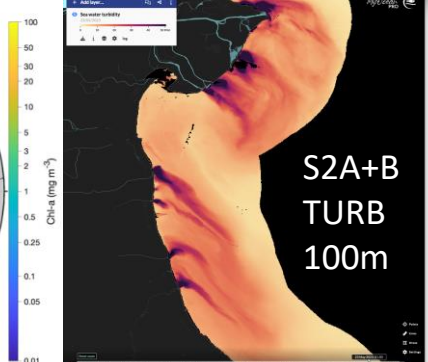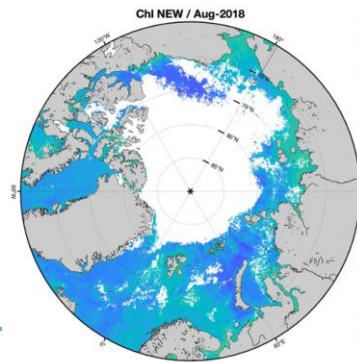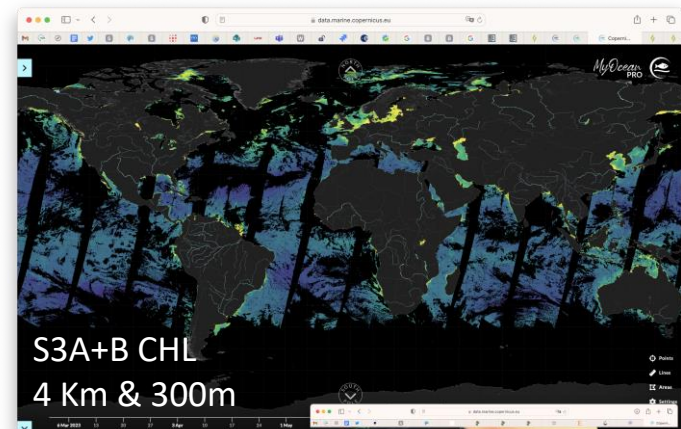With temporal extension first each year, now each 6 months
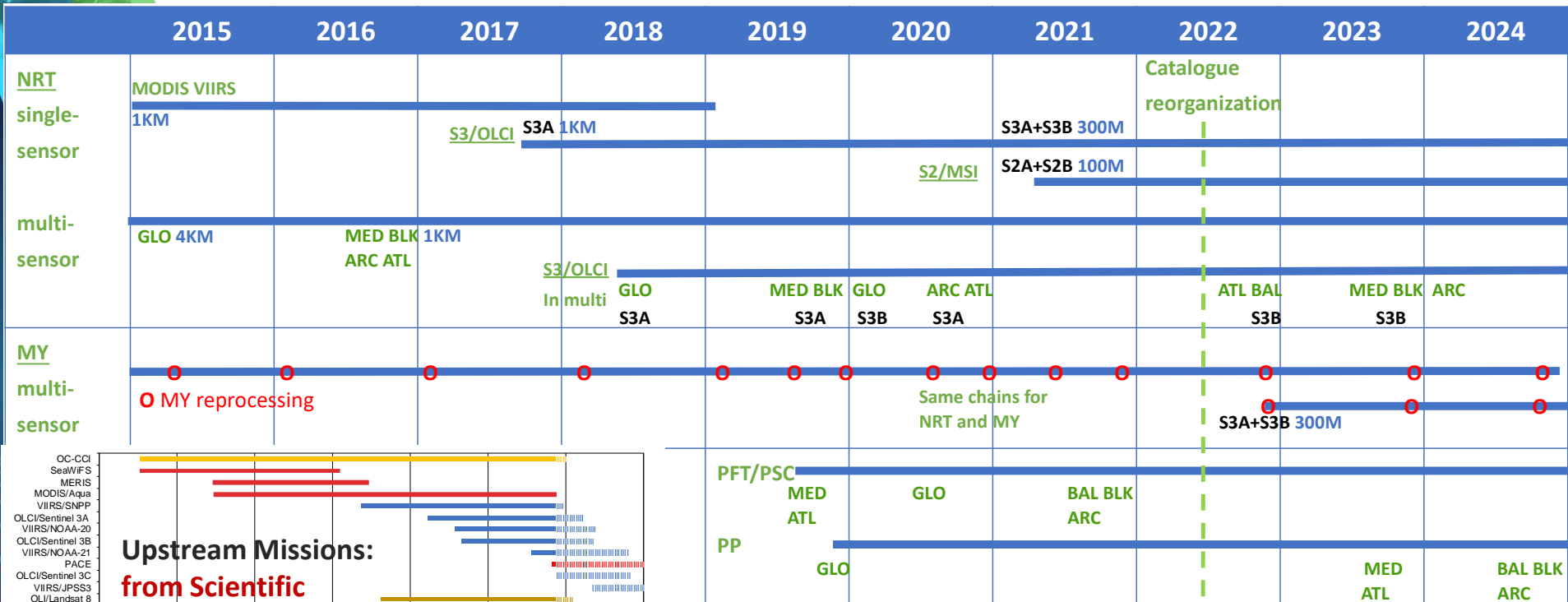
The Ocean Colour TAC

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).

To add value to standard products delivered by the space agencies, OCTAC products are provided at **global scale and at the regional scales** of European seas across four resolutions**:**

- Multi-sensor 1km (Regions) , 4km (GLO)
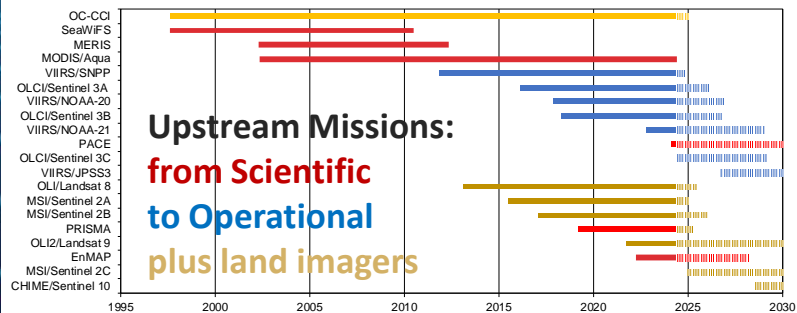- Sentinel-3 OLCI A+B 300m
- Sentinel-2 MSI A+B 100m

S3A+B CHL
4 Km & 300m

S2A+B
TURB
100m

Copernicus
Marine Service

Development of the OC TAC Portfolio

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
NRT single-sensor	MODIS VIIRS 1KM		S3/OLCI	S3A 1KM			S3A+S3B 300M	Catalogue reorganization		
							S2A+S2B 100M			
							S2/MSI			
multi-sensor	GLO 4KM	MED BLK 1KM ARC ATL	S3/OLCI In multi	GLO S3A	MED BLK S3A	GLO S3B	ARC ATL S3A	ATL BAL S3B	MED BLK S3B	ARC
MY multi-sensor	O MY reprocessing						Same chains for NRT and MY	S3A+S3B 300M		

	OC-CCI	PFT/PSC							
	SeaWiFS		MED ATL	GLO	BAL BLK ARC			MED ATL	BAL BLK ARC
	MERIS	PP							
			GLO						

Upstream Missions:
from Scientific
to Operational
plus land imagers

OC-CCI
SeaWiFS
MERIS
MODIS/Aqua
VIIRS/SNPP
OLCI/Sentinel 3A
VIIRS/NOAA-20
OLCI/Sentinel 3B
VIIRS/NOAA-21
PACE
OLCI/Sentinel 3C
VIIRS/JPSS3
OLI/Landsat 8
MSI/Sentinel 2A
MSI/Sentinel 2B
PRISMA
OLI2/Landsat 9
EnMAP
MSI/Sentinel 2C
CHIME/Sentinel 10

1995 2000 2005 2010 2015 2020 2025 2030
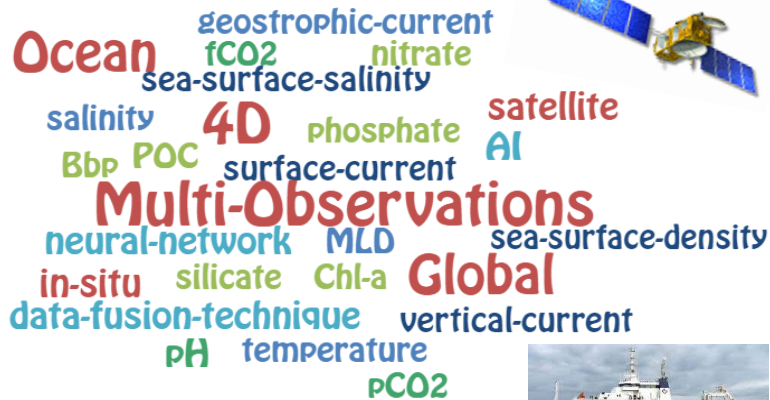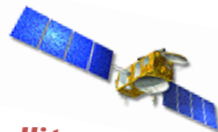
The MULTIOBS TAC

Global qualified Ocean Multi Observations Products

Products based on **Observations** (satellite & in-situ) and **data fusion techniques.**

Products covering **carbon & biogeochemistry.**

Multi-year products

✓ Taking advantage of the **strength of the GOOS**
✓ Staying **close** to the observations
✓ Proving **stable** long timeseries
✓ Proving a **complementary approach** to MFCs

Development of the MULTIOBS TAC Portfolio

New MULTIOBS TAC

Surface Carbon

- 1st release 2001-2016
- +year 2017
- 2nd release 1985-2018
- 3rd release 1985-2019
- 4th release 1985-2020
- 5th release 1985-2021
  New variables: (DIC, Talk, Oca, Oar)
- 6th release 1985-2022
  Resolution increase
- 7th release 1985-2023
  New product name
  New NRT production

- 2 OMIs: Co2 flux, ph averaged
- OMIs update
- OMIs update
- OMIs update
- 3 OMIs: + pH trend
- OMIs update
- OMIs update

Nutrient profiles

- 1st release
- 2nd release + 14 612 profiles
- 3rd release + 53 799 profiles
- 4th release **New variables: (DIC, pH,Talk, pCO2)**
- 5th release + year 2022
- 6th release + year 2023 **New NRT prod consistent with REP**

3D POC/Chl-a

- 1st release 1998-2018
- 2nd release +b_{bp}, 1998-2019
- 3th release 1998-2020
- 4th release 1998-2021
- 5th release Updated method with new upstreams.

Copernicus Marine Service

OUTLINE

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TACs main achievements 2022-2024

- New upstream
- New product/variable
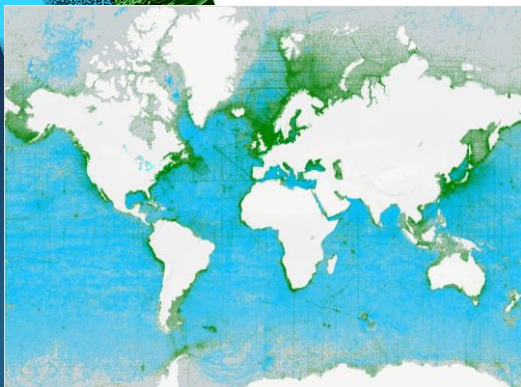- Processing enhancement

Conclusion and perspectives

Development of In Situ TAC portfolio
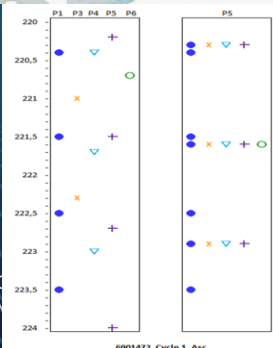
–focus on green ocean

Main achievements

- Harvesting of **> 1000 platforms from EMODnet chemistry** for delayed mode data

- Integration of **bottle data** (physical and biogeochemical measurements) from the Nansen Legacy project in the **Arctic region**, from the Swedish monitoring programme in the **Baltic region**

- Implementation in all regions of **NRT QC procedures for the nutrients** set up by the biogeochemical experts

- **Range test** improvement considering **seasonal differences** along the year for the biogeochemical global multiyear product

- Implementation of **synthetic profiles on BGC-argo** allowing having temperature, salinity and oxygen data at the same depth

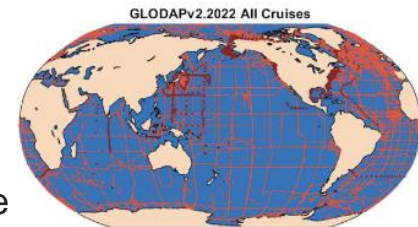# Development of In Situ TAC portfolio
–focus on green ocean

2024 plans

** Global ocean –delayed mode biogeochemical (BGC) product
INSITU_GLO_BGC_DISCRETE_MY_013_046
** Global ocean –delayed mode carbon product
INSITU_GLO_BGC_CARBON_DISCRETE_MY_013_050
** European region – In Situ near real time onservations
INSITU_*region*_PHYBGCWAV_DISCRETE_MYNRT_013_0*XX*
Region = global (GLO), Arctic (ARC), Baltic (BAL), North West EU (NWS), South West EU (IBI), Mediterranean (MED), Black Sea (BLK)

- Enhancement of **QC procedure for chlorophyll** in all NRT regional products considering what first done for global multiyear product

- **Full reprocessing**, temporal extension and quality improvement of the BGC product

- Integration of **new data** (profiles with valid profiles of oxygen, nutrients, chlorophyll-*a*) from **GLODAP dataset** into the BGC product

- **Improvement of regional range tests** with additional reference data from the World Ocean Atlas 2023 (WOA2023)

- **Latest versions of SOCAT** (surface ocean CO2 atlas) **and GLODAP** to build the carbon product

GLODAPv2.2022 All Cruises

Global Ocean Data Analysis Project - GLODAP

Copernicus Marine Service

OCTAC catalogue reorganisation in 2023 due to post-Brexit handover

Changes of PUs and processing chains for Arctic and Atlantic Oceans
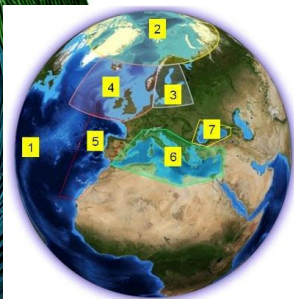
CMEMS Region	multi sensor 1km(Regions), 4km(ARC, GLO)				Sentinel-3 OLCI A+B 300m (Regions) 4km (GLO)				Sentinel-2 MSI A+B 100m			
	NRT		MY		NRT		MY		NRT		MY	
	L3	L4	L3	L4	L3	L4	L3	L4	L3	L4	L3	L4
Arctic Ocean			✓	✓	✓	✓	✓	✓	✓	✓		
NE Atlantic Ocean	✓	✓	✓	✓	✓	✓	✓	✓	✓*	✓*		
NE Atlantic Ocean			✓				✓					
Baltic Sea			✓	✓	✓	✓	✓	✓	✓	✓		
Black Sea	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Mediterranean Sea	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Global			✓	✓								
Global	✓	✓	✓	✓	✓	✓	✓	✓				

Processing Levels:

L3: daily

L4: daily gap-filled and monthly averages

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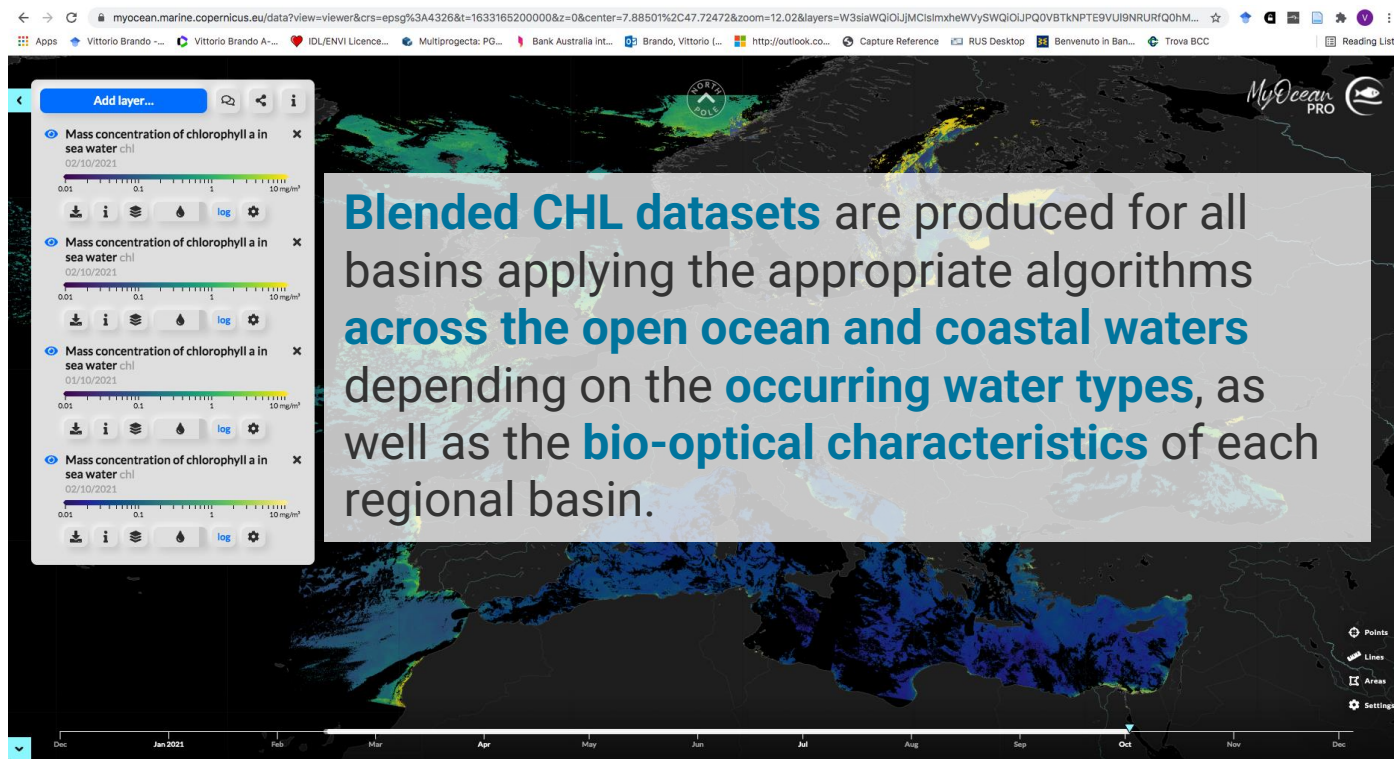
MY: Multy Year reprocessed Time series

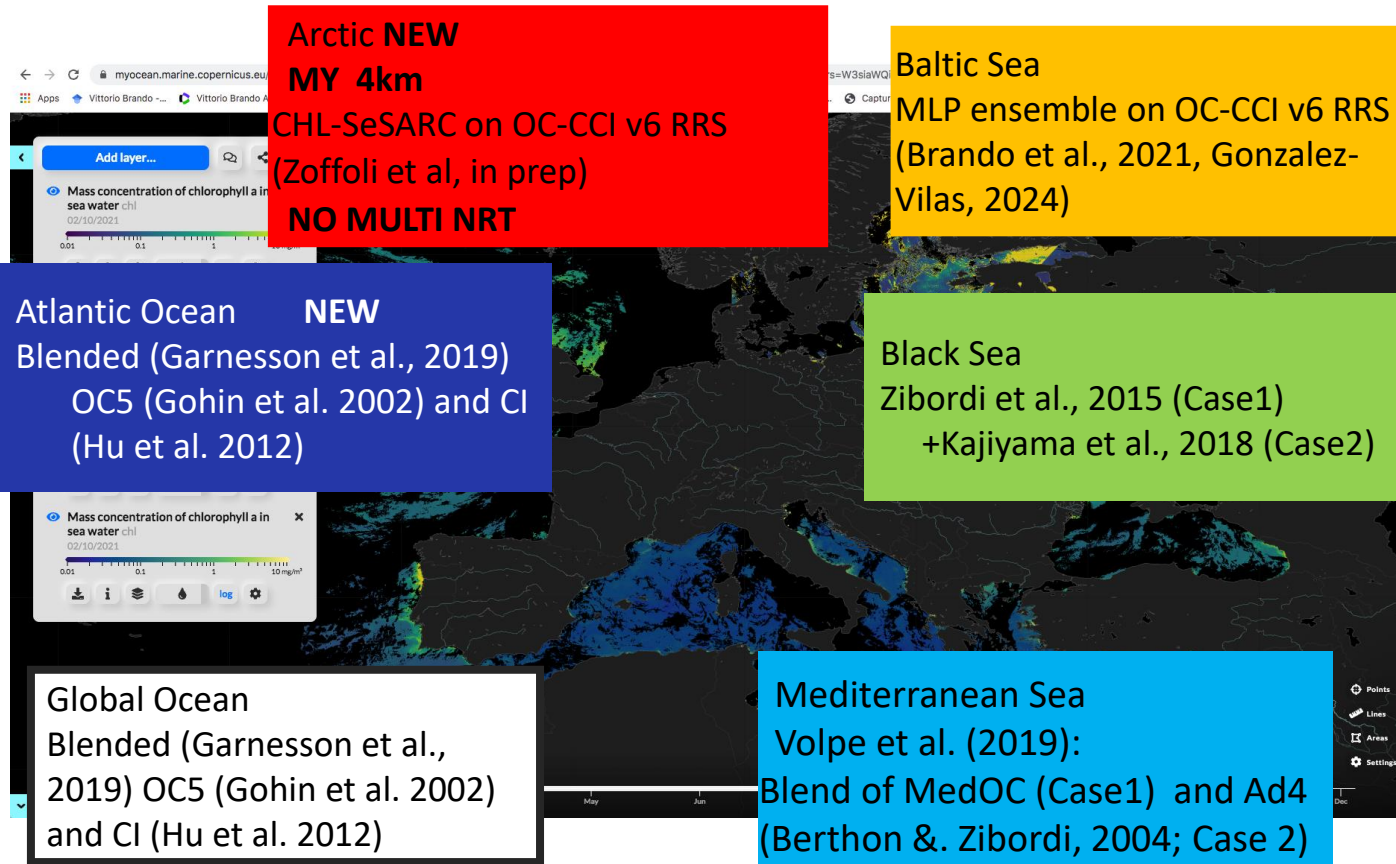* the Sentinel-2 based products for the North Atlantic is produced over the IBI and NWS areas

The Ocean Colour TAC – product overview (November 2023)

MULTI at 1 km /4 km
MY 1997-/31/12/2021
NRT/MYINT 1/1/2022 ->
Regional Seas 1 km
Global 4 km

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 (November 2023)

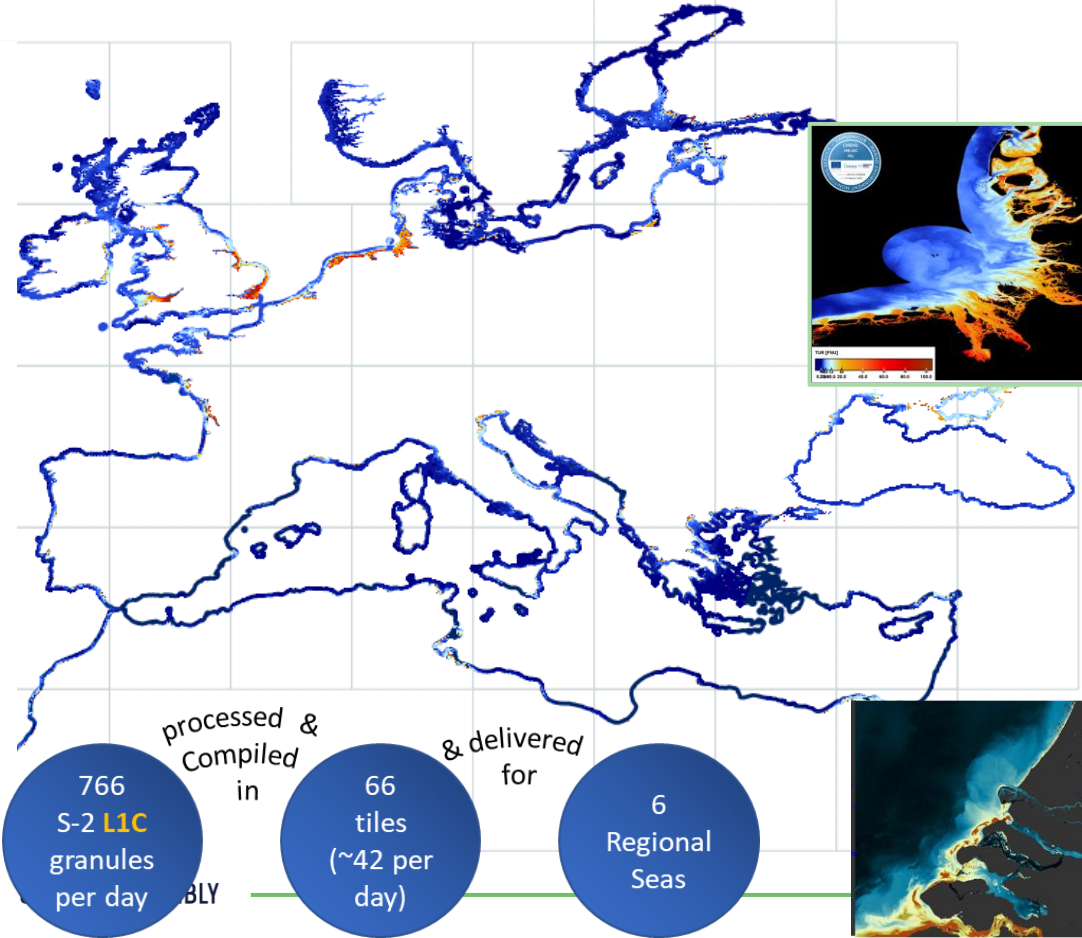**MULTI at 1 km /4 km**
MY 1997-/31/12/2021
NRT/MYINT 1/1/2022 ->
Regional Seas 1 km
Global 4 km

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

Arctic **NEW**
MY 4km
CHL-SeSARC on OC-CCI v6 RRS
(Zoffoli et al, in prep)
NO MULTI NRT

Baltic Sea
MLP ensemble on OC-CCI v6 RRS
(Brando et al., 2021, Gonzalez-
Vilas, 2024)

Atlantic Ocean   **NEW**
Blended (Garnesson et al., 2019)
    OC5 (Gohin et al. 2002) and CI
(Hu et al. 2012)

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

Global Ocean
Blended (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)

The Ocean Colour TAC – product overview (November 2023)

OLCI (S3A+B) at 300m
MY 2016-30/3/2023
NRT/MYINT 1/04/2023 ->
Regional Seas
Global (Coastal = 200km)
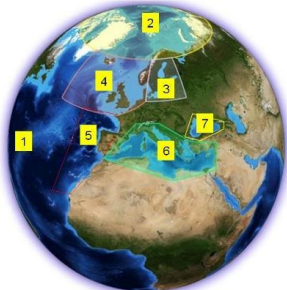
Regionalisation of processing chains takes into account the **bio-optical characteristics of each regional sea.**

Arctic **NEW**
CHL-SeSARC (Zoffoli et al, in prep)

Baltic Sea
MLP ensemble on OC-CCI v6 RRS
(Brando et al., 2021, Gonzalez-Vilas, 2024)

Atlantic Ocean **NEW**
L3: EUMETSAT standard CHL

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

Global Ocean
L3: EUMETSAT standard CHL

Mediterranean Sea
Volpe et al. (2019):
Blend of MedOC (Case1) and Ad4
(Berthon &. Zibordi, 2004; Case 2)
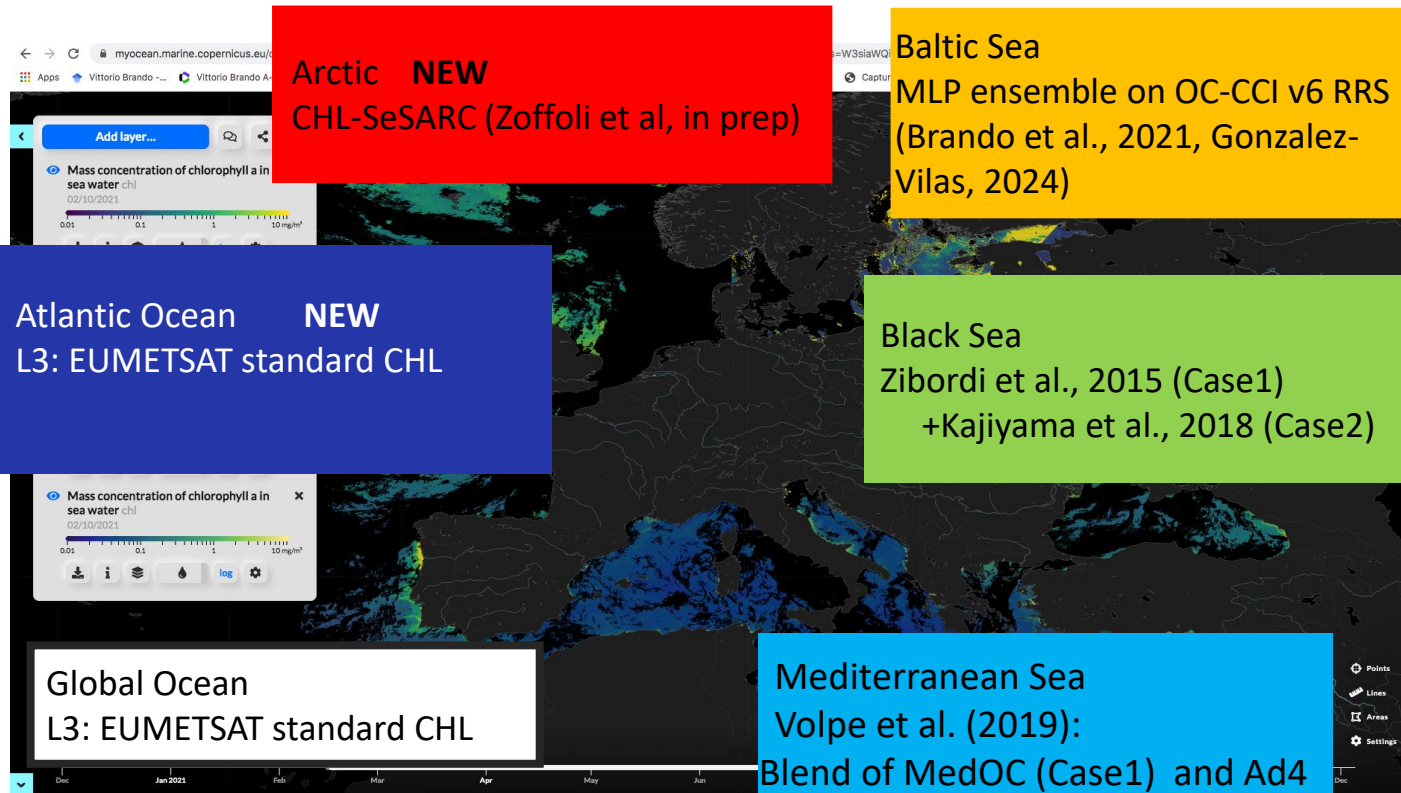
S2 MSI at 100 m
NRT 1/1/2020 ->

Coastal stripes of 20km for European Seas

- L3: daily;

- L4: daily gap-filled and monthly averages

- Download via ftp (nrt.cmems-du.eu)

Parameters

- Remote Sensing Reflectances - RRS(λ)

- Suspended particulate matter – SPM

- Turbidity - TUR

- Particulate Backscatter - BBP(λ)

- Chlorophyll Concentration – CHL
  (one algorithm for all European waters)

processed & Compiled in

& delivered for

766 S-2 **L1C** granules per day

66 tiles (~42 per day)

6 Regional Seas

Ocean Monitoring Indicators

Primary Production Trends from **1997-2022 MY** time series

Primary Production anomalies for 2022

Global MY dataset **at 4 km** resolution

Global Primary Production time series and trend

Datatype : Multi-product
Credit : E.U. Copernicus Marine Service Information

Datatype : Observations
Credit : E.U. Copernicus Marine Service Information

Ocean Monitoring Indicators

Chlorophyll Trends from **1997-2022 MY** time series

Regional MY datasets **at 1 km** resolution

Arctic and Atlantic Oceans not updated in 2023 due to change of PUs and processing chains
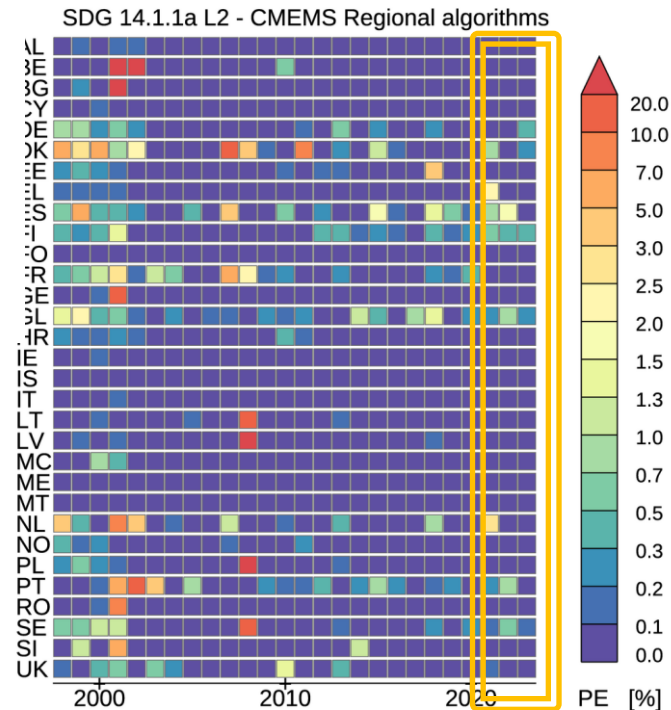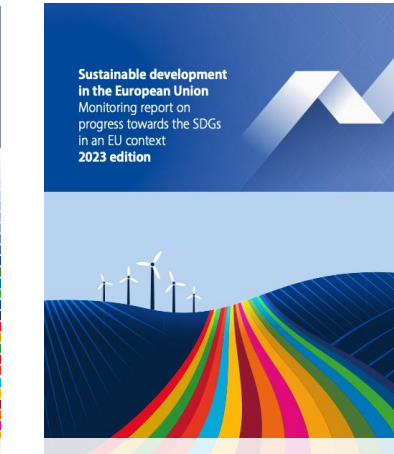
Copernicus Marine Service
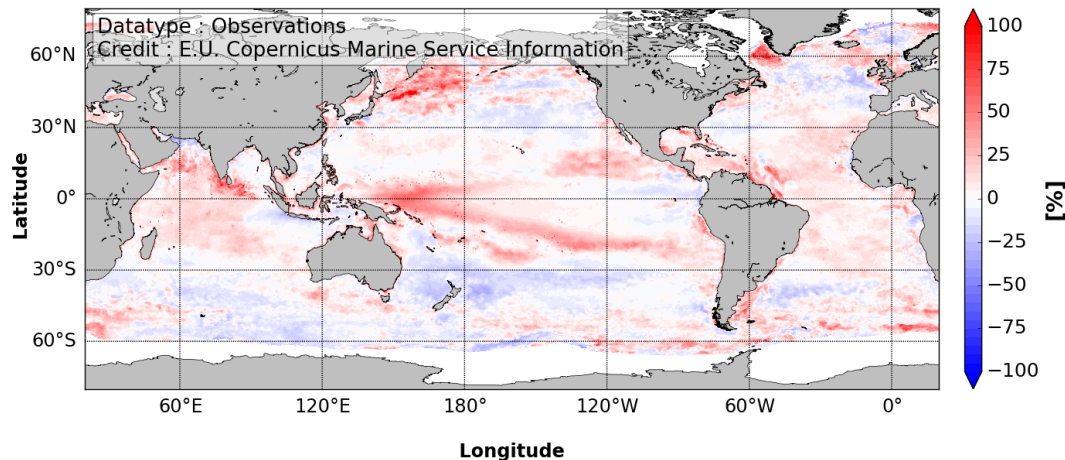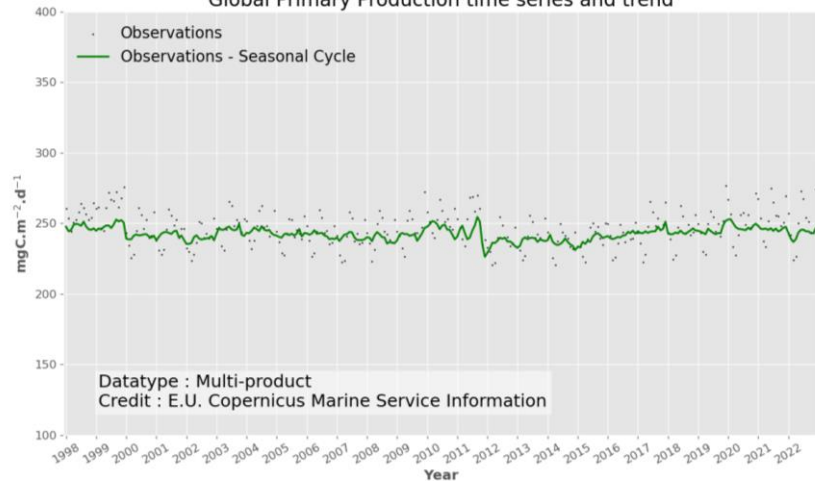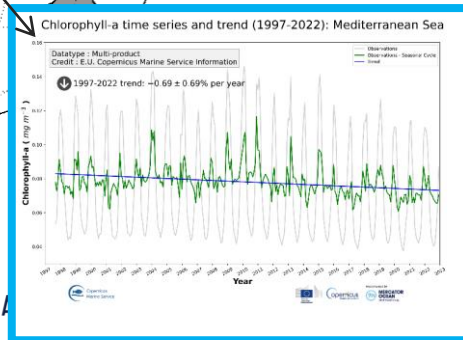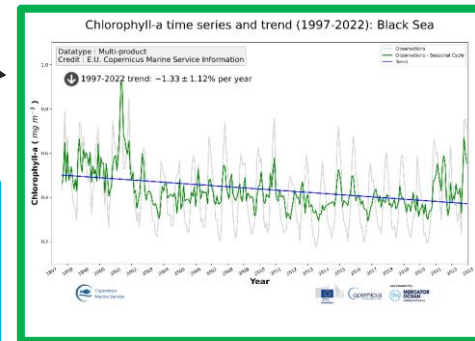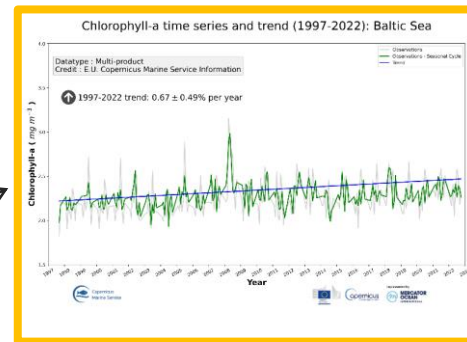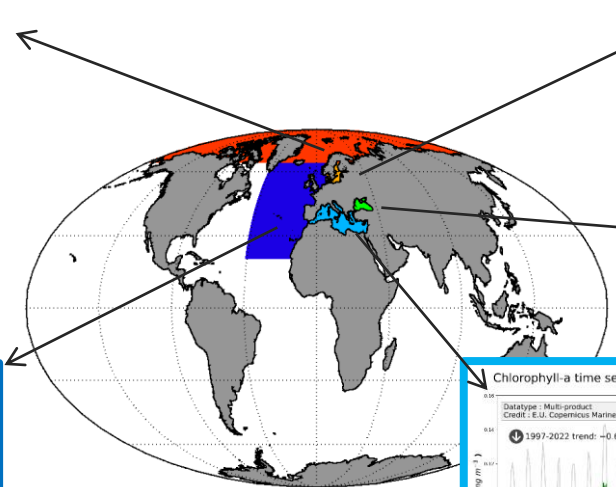
The Ocean Colour TAC – product overview (November 2023)
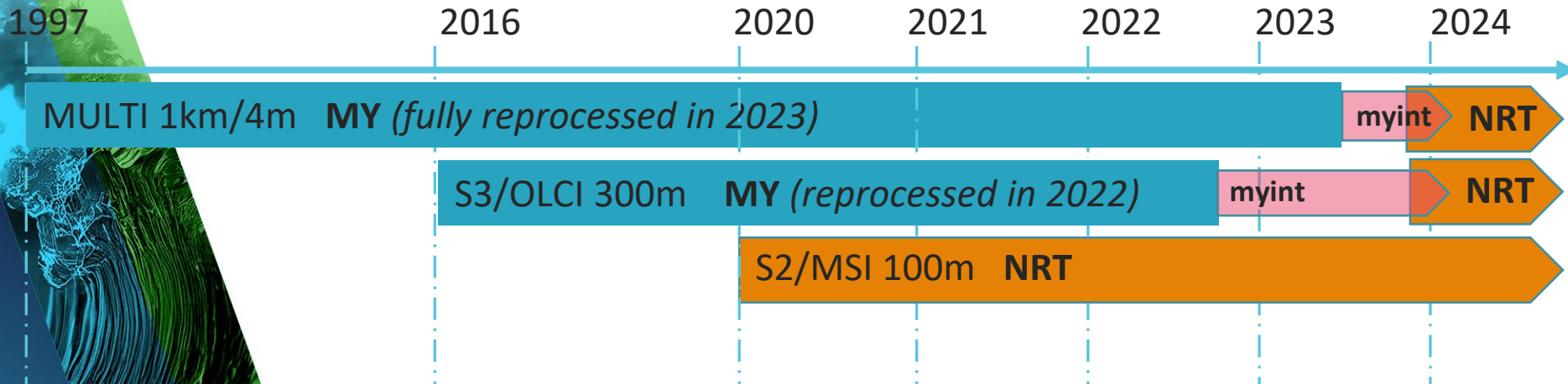## Ocean Monitoring Indicators - Index of coastal eutrophication

Index of coastal eutrophication 1998-2023 time series regional MY datasets **at 1 km** resolution.

Analysis of indicator (SDG 14.1.1a) for each European country is presented in Eurostat's annual monitoring report on Sustainable development in the EU (progress towards SDGs in the EU context).

Sustainable development in the European Union
Overview of progress towards the SDGs in an EU context — 2021 edition

Sustainable development in the European Union
Overview of progress towards the SDGs in an EU context — 2022 edition

Sustainable development in the European Union
Monitoring report on progress towards the SDGs in an EU context — 2023 edition

SDG 14.1.1a L2 - CMEMS Regional algorithms

Data is publicly available at https://ec.europa.eu/eurostat/databrowser/view/sdg_14_60/default/table

The Ocean Colour TAC – Catalogue evolution in 2024

1997   2016   2020   2021   2022   2023   2024

MULTI 1km/4m **MY** *(fully reprocessed in 2023)* → myint → **NRT**

S3/OLCI 300m **MY** *(reprocessed in 2022)* → myint → **NRT**

S2/MSI 100m **NRT**

- **NRT/MY continuity** for each **MULTI** product line (**no MULTI NRT for BAL & ARC**)
- **NRT/MY continuity** for each **S3/OLCI** product line
- **NRT/MYINT continuity: overlap for only one month**
- **Same chains for MULTI and S3/OLCI** for each product line (**apart for GLO**)
- **Same CHL blended algorithms for MULTI and S3/OLCI** for each regional product
- **No** Region-specific products for S2/MSI (postponed to 2025)
- **PFT/PSCs and Primary Production** in NRT and MY for GLO and regions

MOB-TAC 2D surface carbon:

Trang Chau
Frédéric Chevallier
Marion Gehlen

MULTIOBS_GLO_BIO_CARBON_SURFACE_MYNRT_015_008 (new product name)
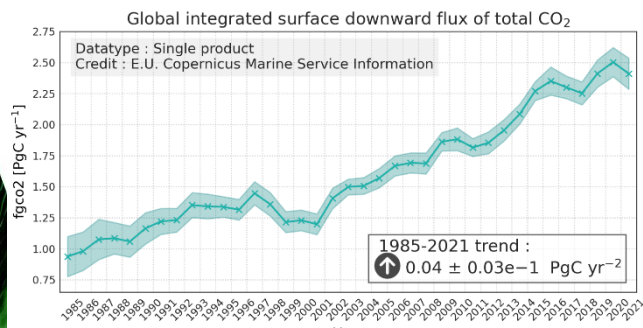
Add NRT M-1 production (new product name/new dataset) in Nov 2024:
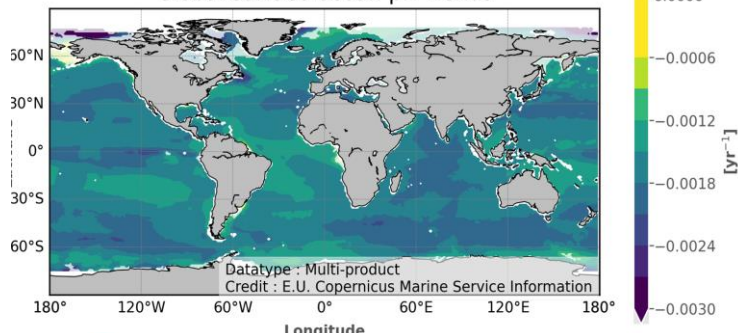Only surface ocean CO2 fugacity and air-sea fluxes.
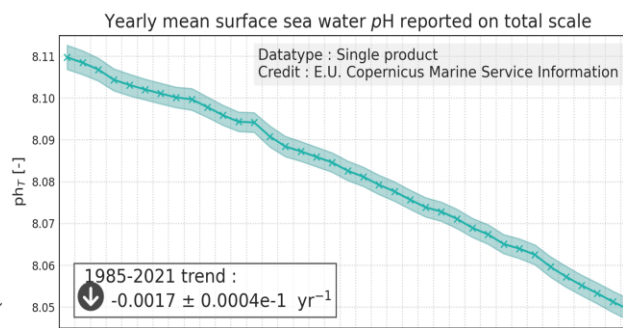
OMIs: global yearly pH time series, global yearly ocean carbon sink, global surface ocean pH trend

MOB-TAC Nutrient vertical profiles:

MULTIOBS_GLO_BGC_NUTRIENTS_CARBON_PROFILES_MYNRT_015_009

Raphaëlle Sauzède
Hervé Claustre
Ana Parracho,
Renosh Pannimpullath
emanan

**In Nov 2024: add monthly production up to M-1**

Nutrient (nitrate, phosphate and silicate) and Carbonate system variables (pH, total alkalinity (AT), dissolved inorganic carbon (CT), and partial pressure of CO2 (pCO2)) vertical profiles derived from BGC-Argo P/T/S/O2 profiles. Based on the neural-network method CANYON trained on nutrient data collected over the last 30 years (GLODAPv2 database)
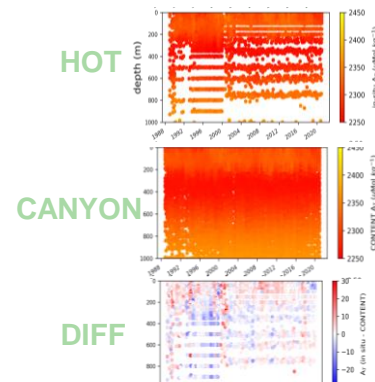
124 017 profiles (Sept 2002– Aug 2022)
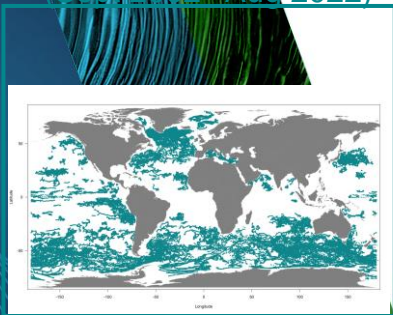
→ take advantage of fast growing number of BGC-Argo profiling floats data
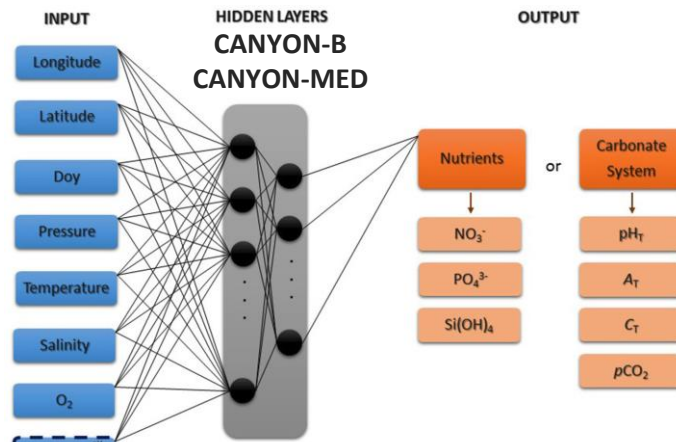
Carbonate system variables compared with observed HOT time series (ex:Total Alkalinity)

HOT

CANYON

DIFF

CANYON-B: CArbonate system and Nutrients concentration from hYdrological properties and Oxygen using a Neural-network. Sauzède et al., 2017, Front. Mar. Sci. 4:128.doi: 10.3389/fmars.2017.00128; Bittig et al., 2018. **CANYON-MED**: Fourrier et al., 2020

MOB-TAC 3D ChIa/ POC (+B_{pp}):

Raphaëlle Sauzède
Hervé Claustre
Ana Parracho,
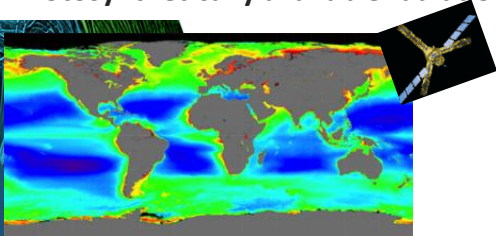Renosh Pannimpullath
Remanan

MULTIOBS_GLO_BGC_3D_REP_015_010
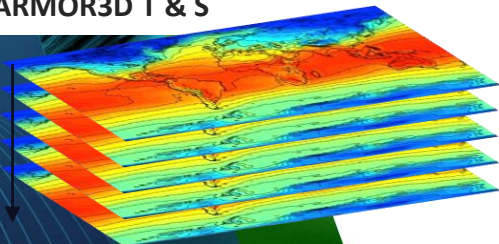**Global 3D POC/bbp and Chla from satellite products**

Based on the neural-network method SOCA trained on BGC Argo bbp (bio-optical proxy of POC) and chla profiles - data collected from BGC-Argo floats and applied on satellite products - 2010 to 2021 – satellite matchups only

SLA

Satellite L3 ocean color (**Remote sensing reflectance, Photosynthetically available radiation (PAR))**

GLOBAL
1/4° resolution
B_{bp}: 36 levels (0-1000m)
Chl: 50 levels up to 1,5 times ZNORM depth
weekly + clim
REP: 1998-2022

B_{bp}, POC, Chla

ARMOR3D T & S

SOCA Neural-Network

SOCA: Satellite Ocean-Color merged with Argo. Sauzède, R., H. Claustre, J. Uitz et al. (2016), A neural network-based method for merging ocean color and Argo data to extend surface bio-optical properties to depth: Retrieval of the particulate backscattering coefficient, J. Geophys. Res. Oceans, 121, doi:10.1002/2015JC011408.
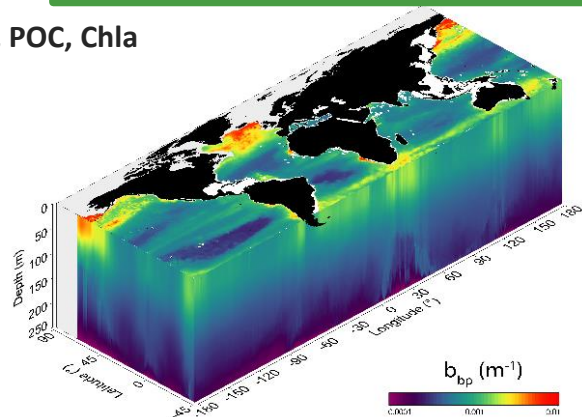
b_{bp} (m^{-1})

Copernicus
Marine Service

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- In Situ TAC
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- Multi Observations TAC

TACs main achievements 2022-2024

- New upstream
- New product/variable
- Processing enhancement

Conclusion and perspectives

Perspectives

Enhanced integration and validation of biogeochemical data to widen the view towards Ocean health and to contribute to boost the improvement of the BGC modelling and assimilation capabilities and of the future Digital Twin of the Ocean.

Continue the integration of recently developed and upcoming ocean observing capabilities measuring BGC variables on **coastal and polar regions**

- Improve the accuracy of the current EOVs at basin level and in coastal areas with particular attention to the shelf and coastal zone.

- Include new biogeochemical EOVs related to the Carbon cycle for in situ and satellite