The importance of FRM in operational ocean colour products for Copernicus/CMEMS

Rosalia Santoleri (Vittorio Brando) and CMEMS

Consiglio Nazionale delle Ricerche

Marine Monitoring

European Commission | Copernicus Europe's eyes on Earth

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Marine Monitoring

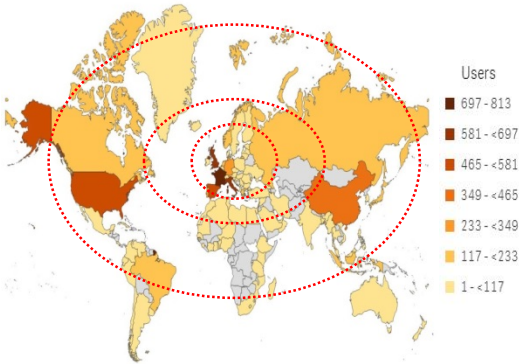
Structure of the talk

- Copernicus Marine Environment Monitoring Service (CMEMS)
- The Ocean Colour Thematic Assembly Center
- in-situ observations used by OCTAC
- Present needs, and future requirements for FRMs

Marine Monitoring

Introduction

The Copernicus Marine Environment Monitoring Service (CMEMS) provides **regular and systematic reference information on the physical state, variability and dynamics of the ocean and marine ecosystems** for the global ocean and the European regional seas with **a free open access to the datasets.**



More than 12 000 subscribers (~ + 200 new subscribers/month)

Downloads (2017) : 290 000+

Downloaded Volume (2017) : 371 Tb,

User satisfaction (2017) : 4,7/5

European Commission

Copernicus Europe's eyes on Earth

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The Copernicus Marine Service: drivers

Marine Monitoring

- **Support a sustainable ocean and blue growth**

Coastal Environment, Marine policies and public information, Marine operation and Safety, Marine Pollution, Research, Climate, New Services.

- **Provide pioneering solutions**

Operational and scientifically assessed, Worldwide and European-wide coverage, long-term sustainability, thousands of users.

- **Provide Open and easy access to marine data**

Open and free data policy, network of producers throughout Europe, Modular organization, Common standards, Single point of access.

European Commission

Europe's eyes on Earth

The Copernicus Marine Service

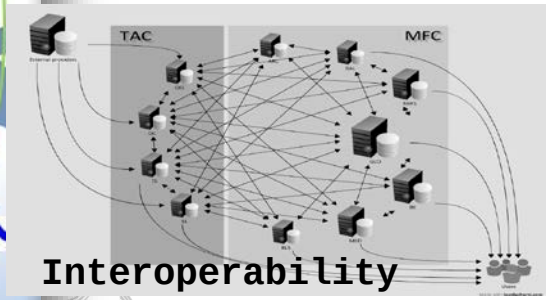
Marine Monitoring

Mercator Ocean entrusted by the European Commission to implement the Copernicus Marine Service, with the support of an extended network

Space data

In-situ data

Computing



Interoperability Protocols

European Commission

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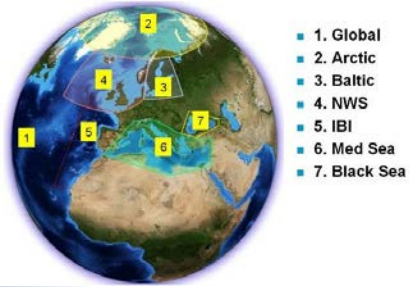
CMEMS Products

Marine Monitoring



★ Global ocean and the European basins

A unique catalogue online.

★ InSitu, Satellite Observations, Modelling products

★ Physical & Biogeochemical variables
- ★ Long time series (25 years)
- ★ Real time products

Full OPEN and FREE service for any application related to Ocean & Seas.

European Commission

Copernicus Europe's eyes on Earth

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The Copernicus Marine Service: products

Marine Monitoring

Reanalysis
10 to 45 years

Real-Time
Daily Hourly

Forecast
2 to 10 days

~ 160 Products

European Commission

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Copernicus Marine Environmental Service: System

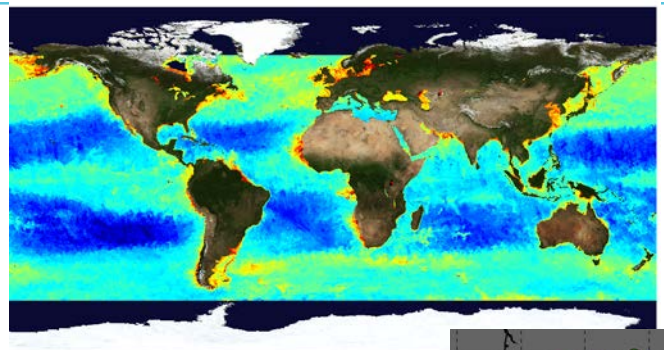
Marine Monitoring

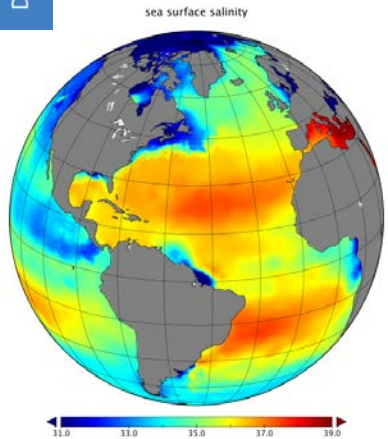
CMEMS is a System of Systems composed by:

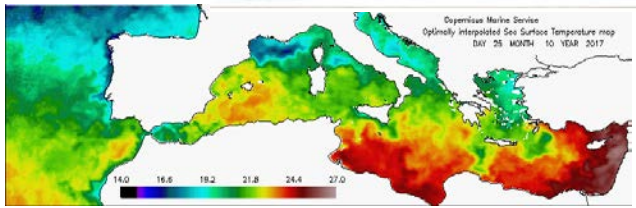
- **8 Thematic Assembling Centres** (TACs) for observation
- **7 Modelling Forecasting Centres** (MFC)
- **1 Dissemination Service** (archiving all the data and disseminating the products to the users)

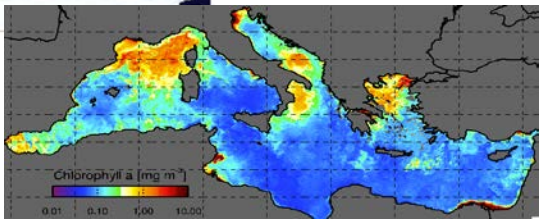
DISSEMINATION SERVICE

MOB PC	SL PC	SST PC	OC PC	WAVE PC	WIND PC	SEA ICE PC	IN SITU PC









European Commission

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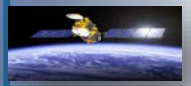
The Copernicus Marine Service

Marine Monitoring

ESA; EUMETSAT; Direct agreement with other space agencies

L1 / L2 Space data



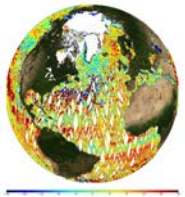
In situ observations

CMEMS Thematic Assembly Centers

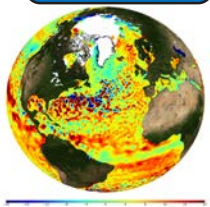
- SL
- OC
- SST
- SI
- WAVE
- WIND
- MOB
- In Situ (INS)

CMEMS Monitoring and Forecast Centers

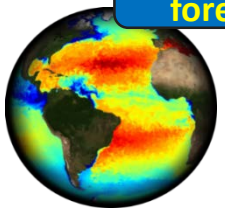
L3 Products



L4 Products



Analysis and forecasts



European Commission

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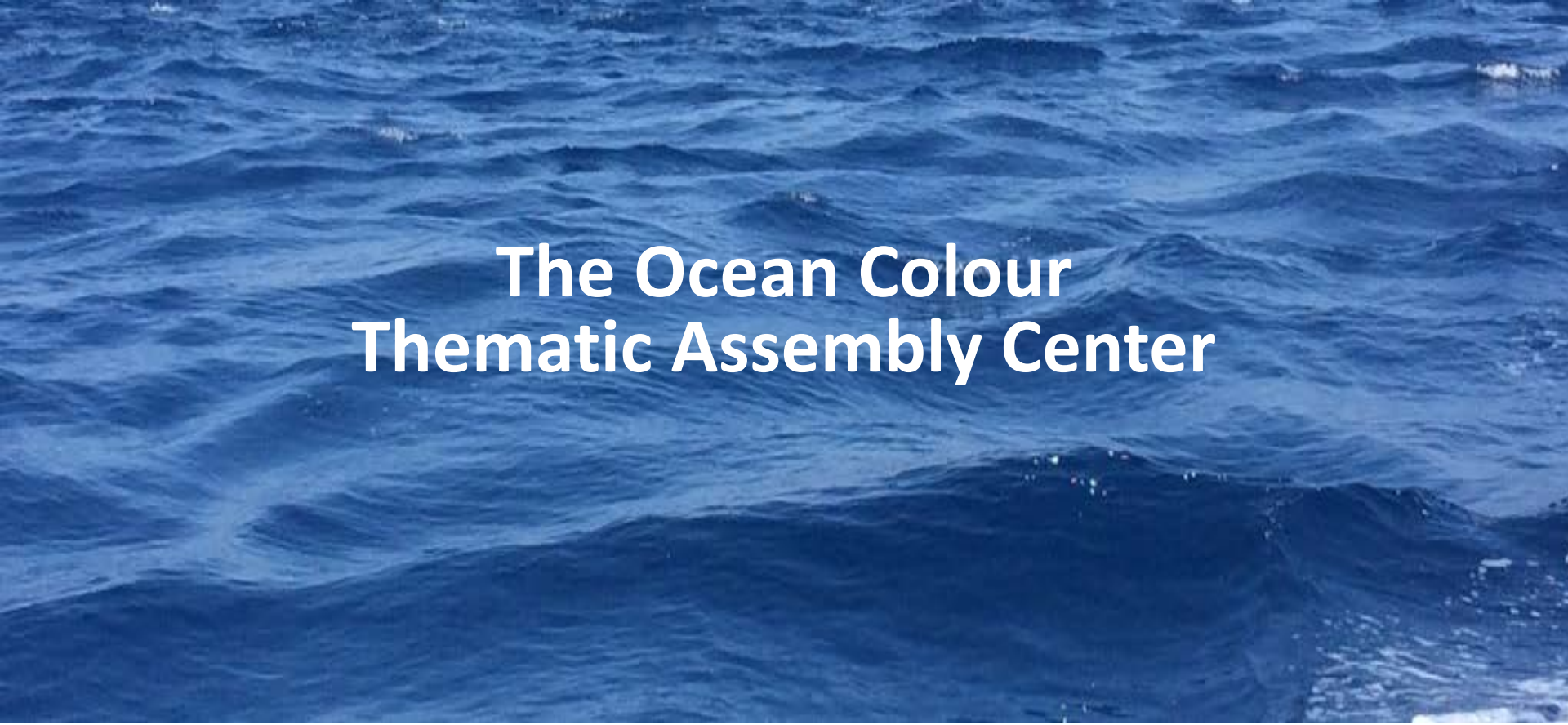


The Ocean Colour Thematic Assembly Center

OCTAC CMEMS

COPERNICUS · MARINE ENVIRONMENT MONITORING SERVICE
CMEMS OCEAN COLOR TAC

The Ocean Colour Thematic Assembly Center

National Research Council of Italy

ACRI ST

PML Plymouth Marine Laboratory

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

SYKE

Æquamra consulting

adwäisEO

OCTAC CMEMS

The OCTAC operates the European Ocean Colour component within the CMEMS, bridging the gap between space agencies, providing ocean colour data, and all users that need the **added-value information not available from space agencies.**

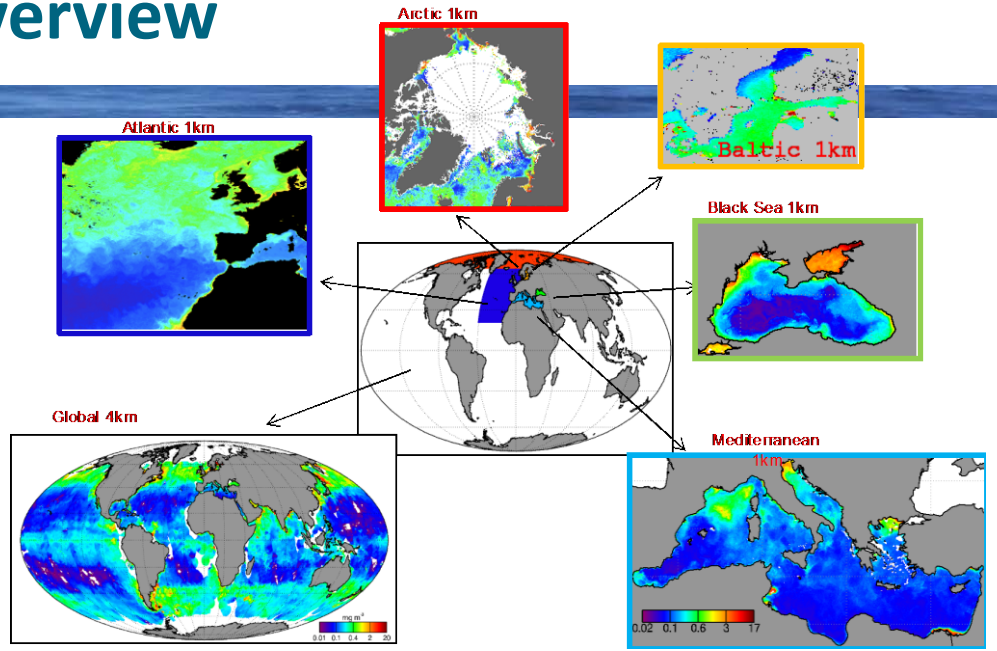
The geographic domain covered by the CMEMS OCTAC is the **Global Ocean** and the European regional seas: **Mediterranean, Black Sea, North Atlantic, Baltic** and **Arctic** seas**.**

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

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

Product Overview

CMEMS Region	Processing Mode	Processing Level
Baltic Sea	NRT/DT/REP	L3/L4
Black Sea	NRT/DT/REP	L3/L4
Mediterranean Sea	NRT/DT/REP	L3/L4
European Sea	NRT/DT	L3
Global Ocean	NRT/REP	L3/L4
Atlantic Ocean	NRT/REP	L4
Arctic Ocean	NRT/DT/REP	L3/L4
Atlantic Ocean	NRT/DT/REP	L3
Global Ocean	REP	L3/L4



L3 (daily composite products, **single/multi-sensor)**

L4 (daily interpolated and weekly/monthly **composites)**

CHL & OPTICS (Rrs ,IOPs , Kd490, Secchi depth, PAR, SPM)

Regional products produced using regional algorithms to improve their quality

NRT: produced within few hours, NRT replaced within few days by consolidated product **(DT)**

REP: consistent re-processed time series (updated/extended once a year, 1997:~YYYY-1)

Product quality information available for all products based on CMEMS metrics

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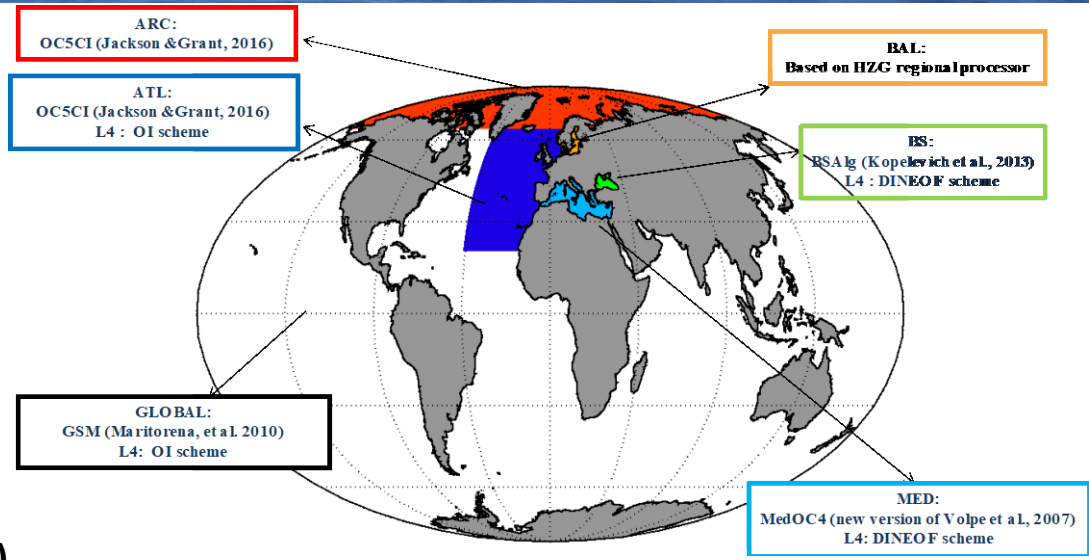
European Sea	NRT/DT	L3
Global Ocean	NRT/REP	L3/L4
Atlantic Ocean	NRT/REP	L4
Arctic Ocean	NRT/DT/REP	L3/L4
Atlantic Ocean	NRT/DT/REP	L3
Global Ocean	REP	L3/L4



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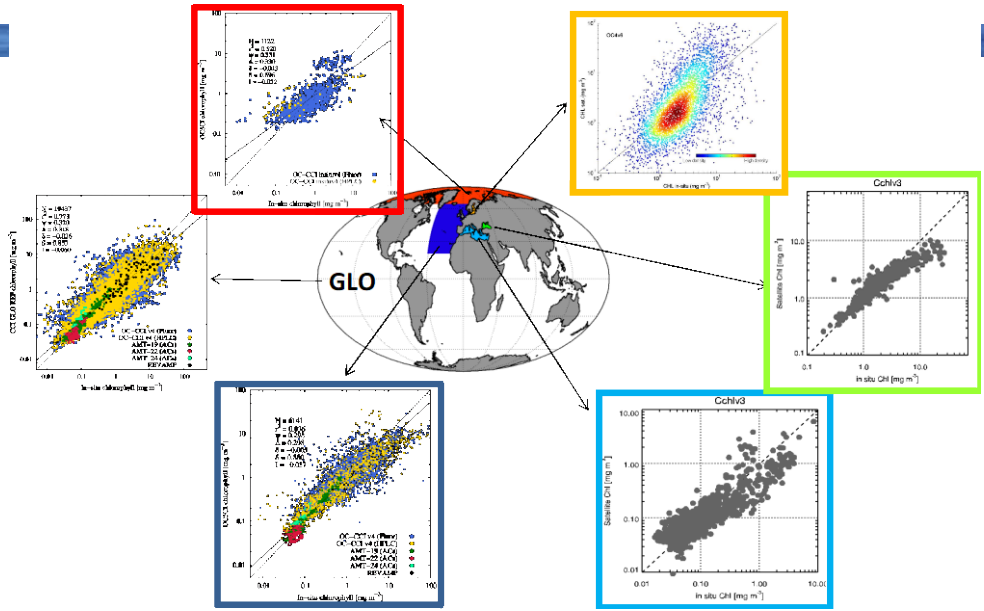
Arctic Ocean	NRT/DT/REP	L3/L4
Atlantic Ocean	NRT/DT/REP	L3
Global Ocean	REP	L3/L4



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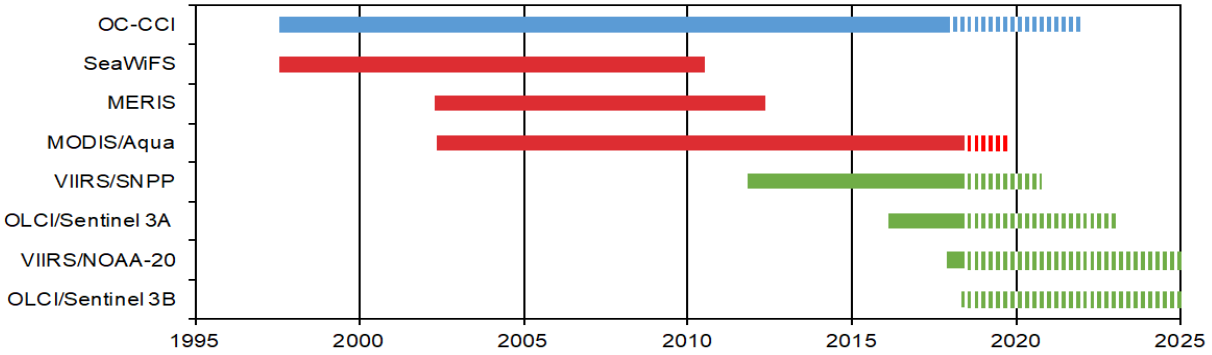
OCTAC evolution 2018-2021

Ingestion of data from the upcoming missions:
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)**

- **Sentinel 3A OLCI** data streams in **multi-sensor** processing chains
- Inclusion of **Sentinel 3B OLCI** & **VIIRS/NOAA-20**
- Improved **Chlorophyll** accuracy for **shelf and coastal waters** (particularly Baltic and Black sea)
- Improvements of **L4 Chlorophyll** products
- **Full resolution** ocean colour (**OLCI 300m**) for European seas
- Global and regional **phytoplankton functional types**
- **Primary production** product at global scale



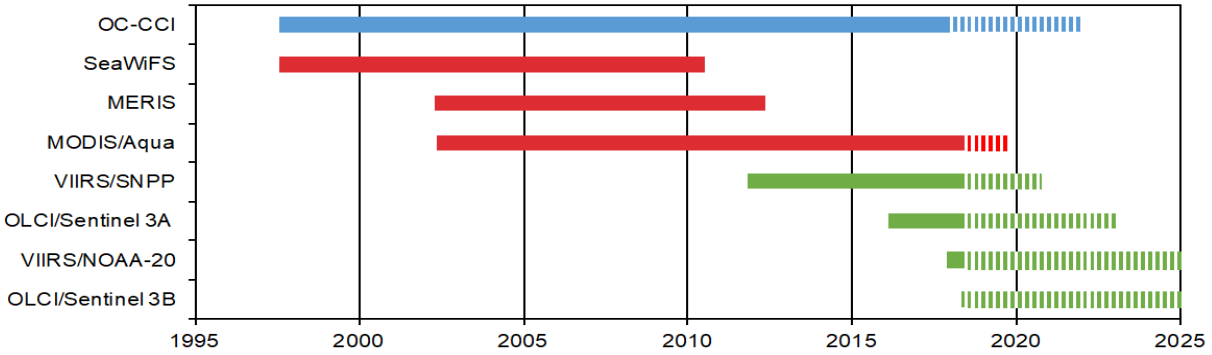
OCTAC upstream evolution

CMEMS (phase 2, April 2018)

- NASA L2 **MODIS** (R2018)
- NASA L2 **VIIRS** (R2018);
- NASA NRT **MODIS** full resolution L1 (Baltic)
- EUMETSAT L1B & L2 Sentinel3A/**OLCI**
- **OC-CCI** multi-sensor (SeaWiFS, MODIS MERIS, VIIRS) L3 reprocessed dataset v3.1 (NASA R2014. MERIS 3rd)

CMEMS 2019/2020/2021

- NASA L2 **MODIS** (**R2018**, ?)
- NASA L2 **VIIRS** (SNPP+**NOAA-20**) (**R2018**, ?)
- NASA NRT **MODIS** full resolution L1 (Baltic)
- EUMETSAT L1B & L2 Sentinel3A+**3B**/**OLCI**
- **OC-CCI** multi-sensor (SeaWiFS, MODIS, MERIS, VIIRS, **OLCI?**) L3 reprocessed dataset v4.v5? (NASA **R2018**. **MERIS 4th**,?)



?? MODIS retirement???

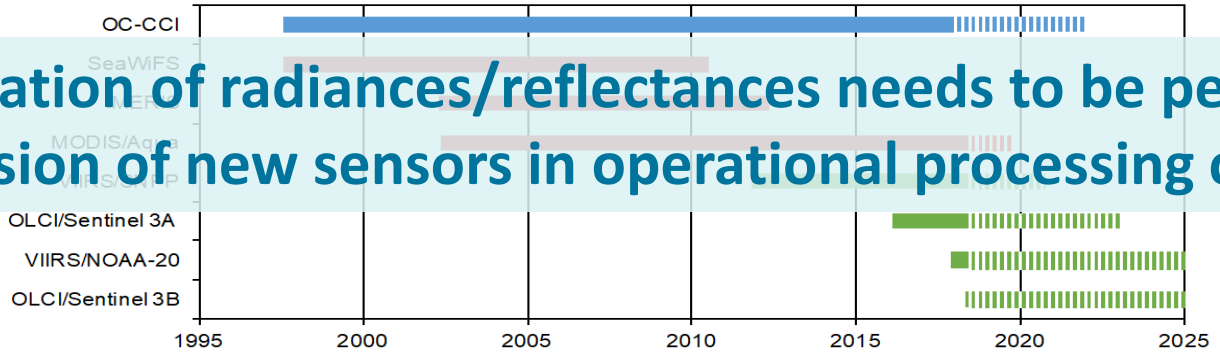
OCTAC upstream evolution

CMEMS V4 (2018)

- NASA L2 **MODIS** (R2018)
  NASA L2 **VIIRS** (R2018);
- NRT **MODIS** full resolution L1 (Baltic);
- **OC-CCI** multi-sensor (SeaWiFS, MODIS MERIS, VIIRS) L3 reprocessed dataset v3.1 (NASA R2014)
- EUMETSAT L1B & L2 Sentinel3A/**OLCI**

CMEMS 2019/2020/2021

- NASA L2 **MODIS** (**R2018**, ?)
  NASA L2 **VIIRS** (SNPP+**NOAA-20**) (**R2018**, ?);
- NRT **MODIS** full resolution L1 (Baltic);
- **OC-CCI** multi-sensor (SeaWiFS, MODIS, MERIS, VIIRS, **OLCI?**) L3 reprocessed dataset v3.2 (NASA **R2018,** ?)
- EUMETSAT L1B & L2 Sentinel3A+**3B**/**OLCI**



Qualification of radiances/reflectances needs to be performed prior to inclusion of new sensors in operational processing chains

importance of FRMs for OCTAC

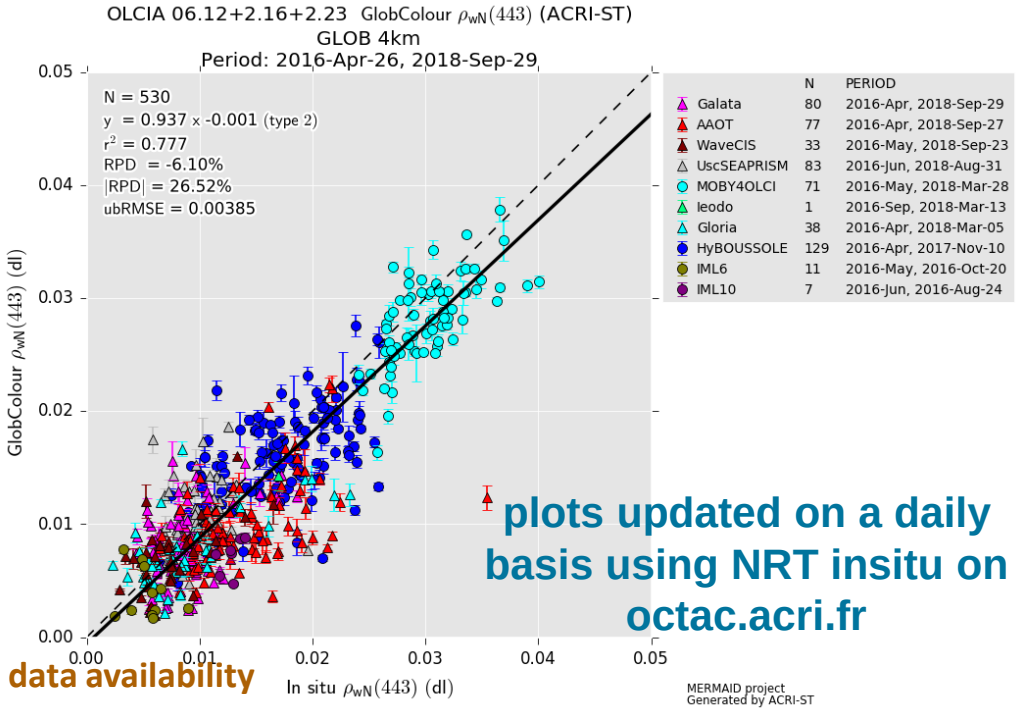
FRMs: status of the in-situ observations used by OCTAC

Ocean Colour variables

- Chlorophyll *a* concentration (Chl)
- Spectral Remote Sensing Reflectance
- Spectral Inherent Optical Properties (IOPs, light attenuation and backscattering)
- Spectral diffuse attenuation coefficient (K_d)

Availability

- Automated radiometry (in- and above-water) at dedicated calibration/validation sites (i.e. MOBY, BOUSSOLE, and AERONET-OC)



AERONET-OC is the only automated system providing data in near-real time

All the other FRMs are non-automated systems strongly dependent on analysis and post-processing: data in delayed time mode

plots updated on a daily basis using NRT insitu on octac.acri.fr

OCTAC CMEMS

Thanks to AERONET-OC Pis efforts for NRT data availability

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- Radiometry, IOPs and biogeochemical (Chl, TSM) during dedicated research cruises:
  - Publicly available bio-optical datasets: SeaBaSS, MERMAID, OC-CCI, etc
  - bio-optical data acquired by the OCTAC partners: AMT cruises (PML), Mediterranean data (CNR), Baltic data (SYKE)

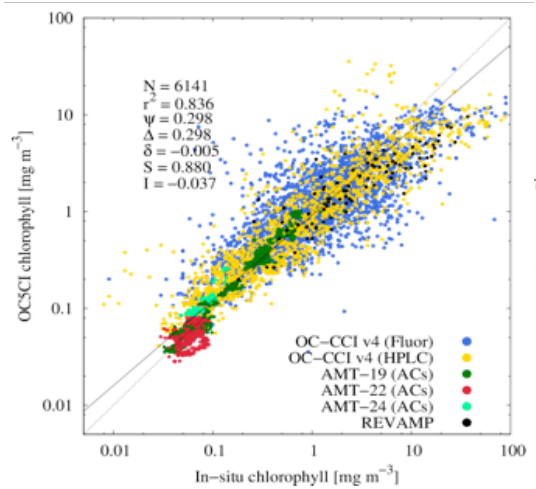

Figure 1: OC5CI vs ATL in-situ

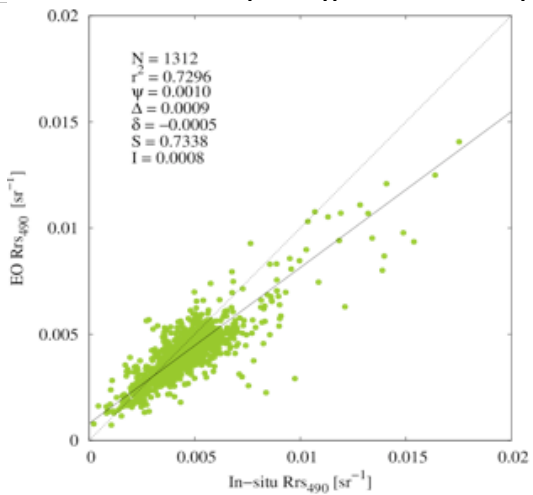

Figure 1: Rrs490 vs ATL in-situ

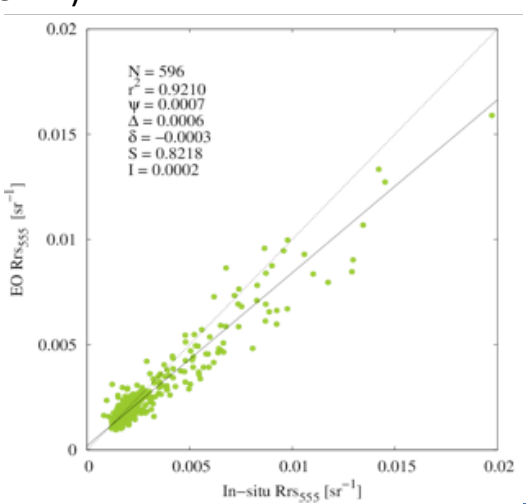

Figure 1: Rrs555 vs ATL in-situ

FRMs: status of the in-situ observations used by OCTAC

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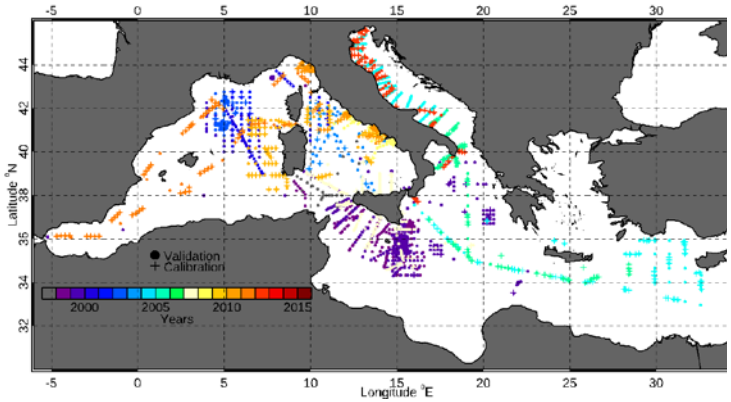

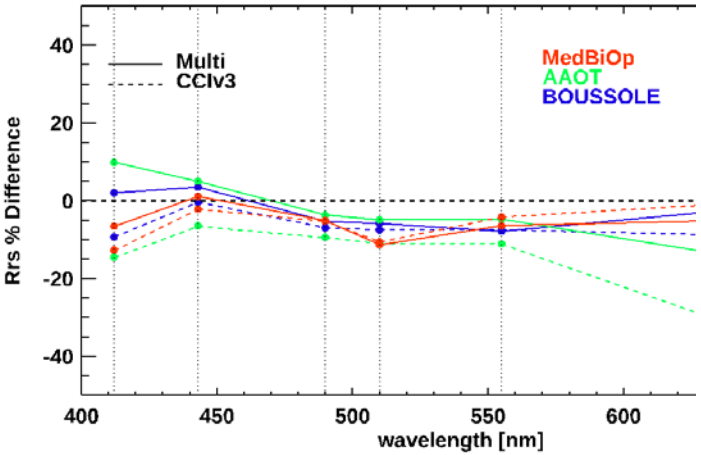

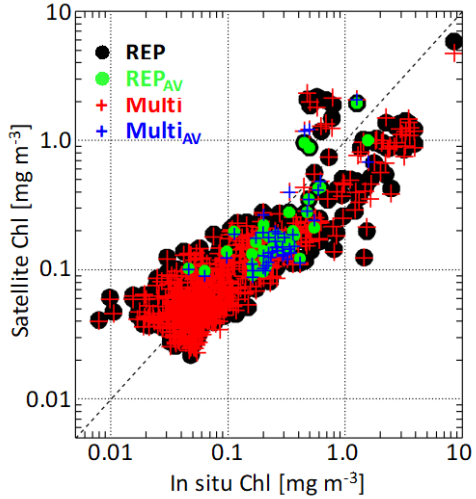

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OCTAC will include products such as primary production, phytoplankton functional groups and size, particle size distribution

These variables are even more scant as they are not performed in all research cruises that analyse water samples.

Chl concentration is measured in lab through fluorometric or spectrophotometric techniques and from high-performance liquid chromatography (HPLC)

Chlorophyll fluorescence methods are NOT deemed of adequate quality for product development or qualification, unless periodically calibrated with HPLC sample measurements

OCTAC CMEMS

FRMs: present needs, and future requirements

- ***Moored*** Fixed-Point Observatory for high precision radiometric measurements for **System Vicarious Calibration**
- ***Tower*** Fixed-Point Observatories with **Automated above-water radiometry** for **System Validation**
- ***Moored*** Fixed-Point Observatories with **Automated in-water radiometry** for **System Validation**
- ***Ship based*** Radiometric, IOPs and biogeochemical data from research cruises

- **Spatial and temporal coverage and resolution**

FRMs: present needs, and future requirements

Moored Fixed-Point Observatory for high precision radiometric measurements for **System Vicarious Calibration**

- CMEMS data quality depends on the post-launch SVC
  - Currently SVC is NOT part of Copernicus (Moby @ Hawaii)
- **Europe should invest in an OC-SVC infrastructure dedicated to the Copernicus Programme**
  - EUMETSAT identified a series of steps to achieve this goal and is currently working on preliminary design of the Copernicus OC-SVC infrastructure
  - The system should be designed to allow **NRT data stream** towards the Copernicus space segment and CMEMS for validation purposes

FRMs: present needs, and future requirements

Tower Fixed-Point Observatories with **Automated <u>above-water</u> radiometry** for **System <u>Validation</u>**

- AERONET-OC is currently a network of multi-spectral sensors
  - allowing the validation of a limited number of spectral bands (e.g., only half of the 21 OLCI bands can be validated)
  - The sites are located in **coastal** waters and provide NRT data

- **An evolution towards hyper-spectral sensors is strongly envisaged**
- **At these sites CTD, fluorometry, IOPs as well as biogeochemical water samples should be routinely acquired**

FRMs: present needs, and future requirements

Moored Fixed-Point Observatories with **Automated <u>in-water</u> radiometry** for **System <u>Validation</u>**

- Currently only a few sites in which in-water radiometry is routinely performed using commercial off-the-shelf instrumentation (e.g., BOUSSOLE, Western Channel Observatory and Lampedusa Buoy)
  - These constitute the only sites offering the opportunity for continuous measurements of open water products
  - Here, biogeochemical water samples (and IOPs) are routinely acquired

- **A network of automated moored fixed-point observatories for OC validation should be established, *a la* AERONET-OC**

OCTAC CMEMS

FRMs: present needs, and future requirements

Ship based Radiometric, IOPs and biogeochemical data from research cruises

- To ensure continuity of the in-water radiometry, IOP and biogeochemical measurements from profiles acquired during dedicated research cruises **access to berths needs a long term coordinated effort at the European scale** thus enabling sustained coverage of regional seas
- In addition, an evolution from profiles to continuous (automatic) measurement systems for AOPs and IOPs is envisaged
- Currently **biogeochemical FRMs (i.e. Chlorophyll, TSM) and IOPs** derive from samples collected during dedicated research cruises and are strongly dependent on post-cruise chemical lab analysis or post-processing. As such, they are **only available in delayed time mode** (days, weeks or months). **A wide community effort is needed to improve data timeliness and availability on public databases**
- routine acquisition of parameters needed for the evolution of the ocean colour catalogue (e.g., primary production, phytoplankton functional groups and size, particle size distribution, etc) requires a coordinated community effort

Present needs, and future requirements

Spatial and temporal coverage and resolution

- The introduction of automated above-water radiometry and continuous IOP measurement systems on ships of opportunity would dramatically increase data availability
- Biogeochemical measurements acquired on fixed platforms, ferryboxes or Bio-Argos will surely contribute to increase data spatial and temporal coverage … they need routine calibration and timely post-processing

FRMs: present needs, and future requirements

- ***Moored*** Fixed-Point Observatory for high precision radiometric measurements for **SVC**
  - **Europe should invest in an OC-SVC infrastructure dedicated to the Copernicus Programme**
- ***Tower*** Fixed-Point Observatories with **Automated <u>above-water</u> radiometry** for **<u>Validation</u>**
  - **An evolution towards hyper-spectral sensors is strongly envisaged**
  - **CTD, fluorometry, IOPs as well as biogeochemical water samples should be routinely acquired**
- ***Moored*** Fixed-Point Observatories with **Automated <u>in-water</u> radiometry** for **<u>Validation</u>**
  - **A network of automated moored fixed-point observatories for OC validation should be established, *a la* AERONET-OC**
- ***Ship based*** Radiometric, IOPs and biogeochemical data from research cruises
  - **A wide community effort is needed to improve data timeliness**
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- **Spatial and temporal coverage and resolution**

Marine Monitoring

Thanks for Your attention

European Commission

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