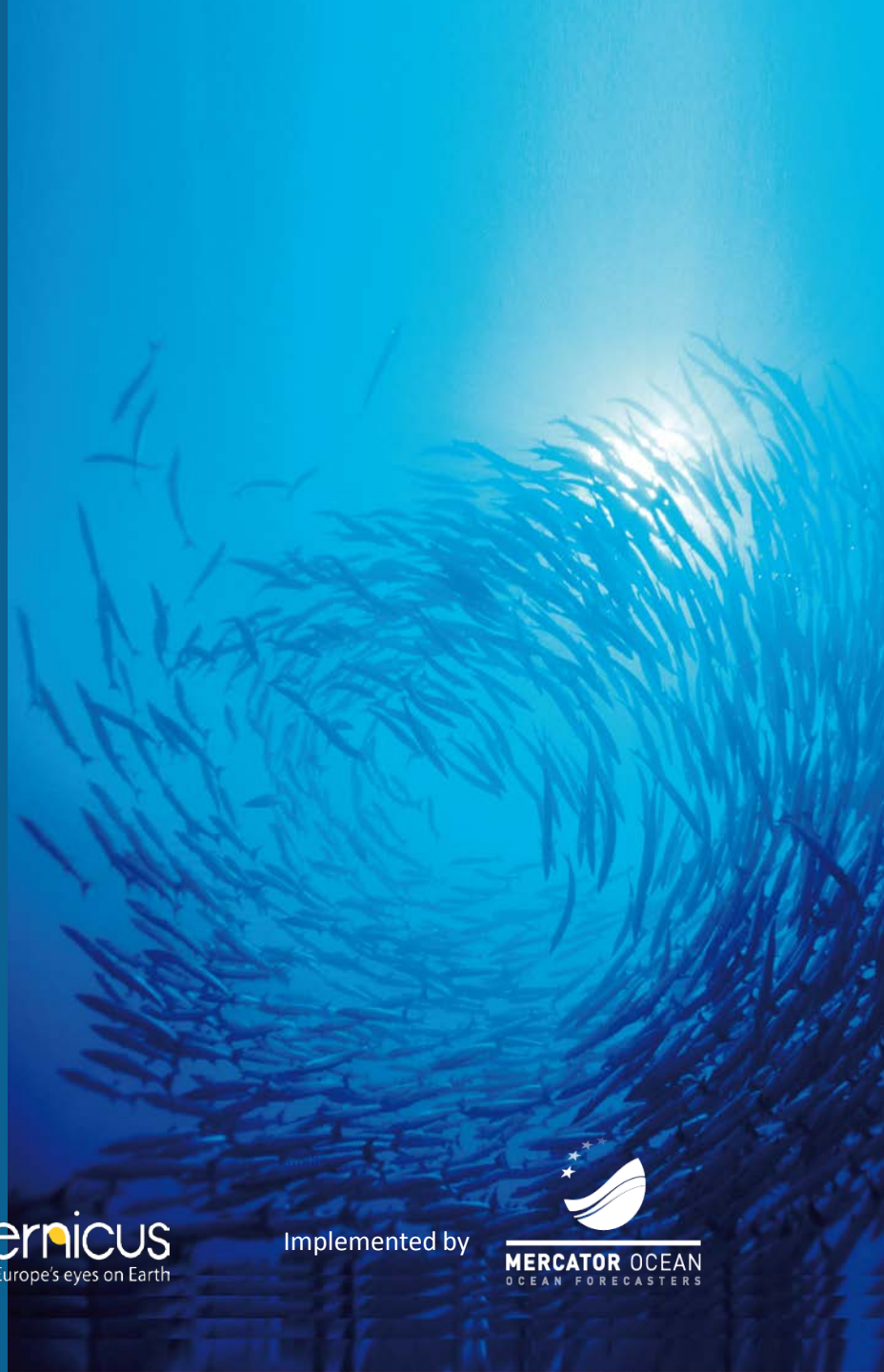
The Copernicus Marine Environment Monitoring Service and its use for marine resource applications

Pierre-Yves Le Traon

Mercator Ocean

Blue Planet Symposium, May 31st 2017



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Implemented by

MERCATOR OCEAN
OCEAN FORECASTERS

Copernicus Marine Service

Organization, products & services, users and applications

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The European Copernicus Programme

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SATELLITES

(S1, S3, Jason-3, S6, S2)

IN SITU

SERVICES

- MARINE
- ATMOSPHERE
- LAND
- SECURITY
- EMERGENCY
- CLIMATE

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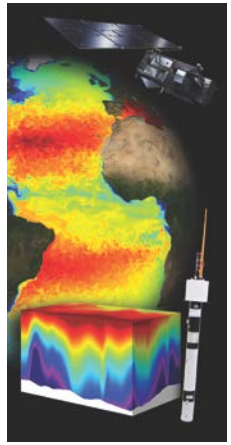
The Copernicus Marine Service

Pressing/increasing needs to monitor the oceans:

- **to understand and predict the evolution of our weather and climate.**
- **for a better and sustainable management of our oceans and seas.**

Copernicus Marine Service Vision: **"A world-leading marine environment and monitoring service, supporting blue growth and the blue economy, for maritime safety, effective use of marine resources, healthy waters, informing coastal and marine hazard services, and supporting climate services"**



Operational Oceanography integrated (observations, models, user services) and science based approach

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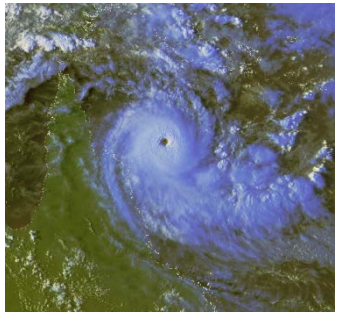
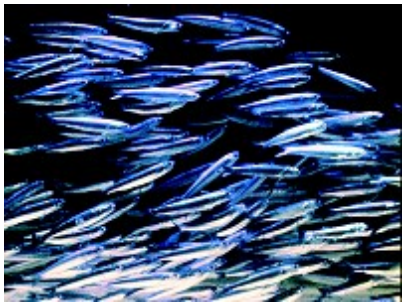
COPERNICUS MARINE SERVICE DRIVERS : CLIMATE + OCEAN HEALTH + OCEAN SERVICES





Climate, decadal and seasonal forecasting

Weather forecasting and extreme events

Fishery management
Aquaculture

Renewable marine energy

Offshore Industry

Maritime Security,
Marine Safety

Navies

Coastal applications, water quality, environmental monitoring and reporting/regulation, coastal hazards

Ocean, climate and ecosystem research

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others…

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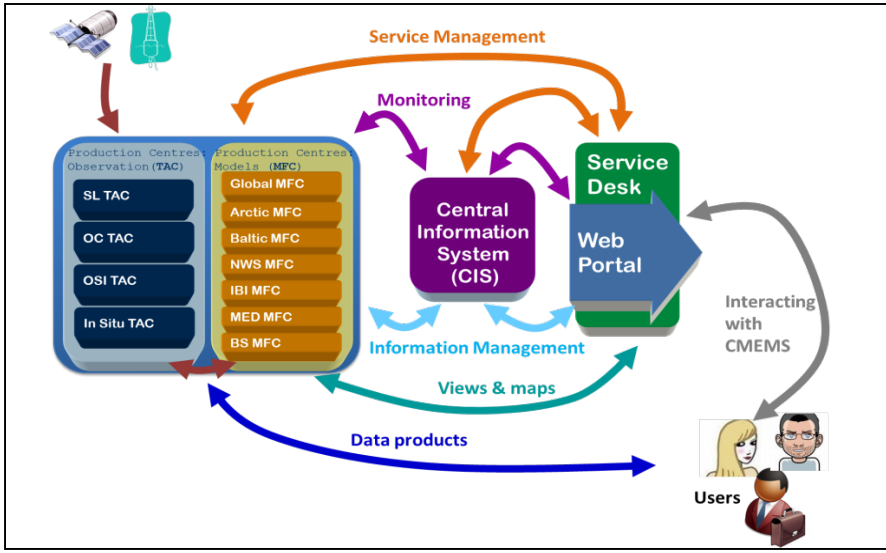
The Copernicus Marine Environment Monitoring Service

A long-term EU Marine Service:

- **Operational** and **scientifically assessed**
- **Observations** (satellite, in-situ) and **models** (analyses/forecasts)
- **Physics** (e.g. sea level, currents, temperature, sea ice) and **Biogeochemistry** (e.g. oxygen, primary production, nutrients)
- A **network** of European producers
- A **unique catalogue**: **Worldwide** and **European-wide** coverage
- A **central information system** to search, view, download products and monitor the system
- A **service desk** to support users who relies on a network of technical & marine experts
- **Generic** to serve a **wide range of downstream applications**. More than **9200 registered users**



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The Copernicus Marine Service

Observations and Models

REPROCESSING REANALYSES
30 years

REAL-TIME
Daily, hourly

FORECAST
2 to 10 days

1 Global
2 Arctic
3 Baltic
4 NWS
5 IBI
6 Med Sea
7 Black Sea

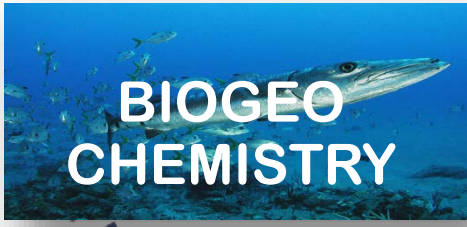
DISCOVER

VIEW

DOWNLOAD

Open & Free

ESSENTIAL OCEAN VARIABLES



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Copernicus Marine Service
Evaluation of product quality

SCIENTIFIC VALIDATION METHODS / METRICS BASED ON INTERNATIONAL STANDARDS

PRODUCT AND PRODUCT QUALITY DOCUMENTATION FOR ALL PRODUCTS

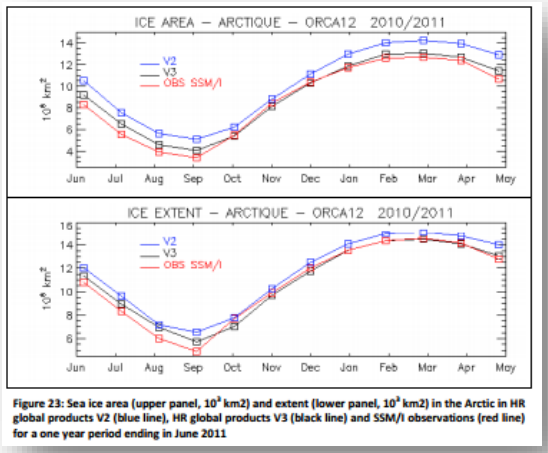
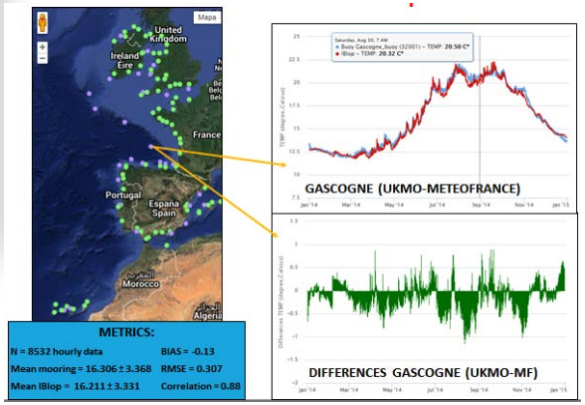


Figure 23: Sea ice area (upper panel, 10^3 km2) and extent (lower panel, 10^3 km2) in the Arctic in HR global products V2 (blue line), HR global products V3 (black line) and SSM/I observations (red line) for a one year period ending in June 2011



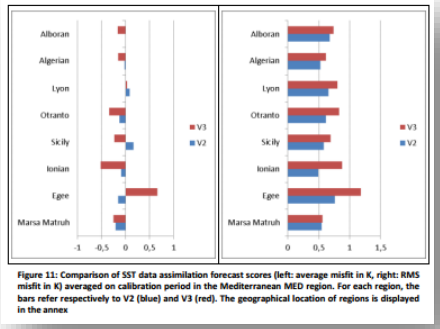


Figure 11: Comparison of SST data assimilation forecast scores (left: average misfit in K, right: RMS misfit in K) averaged on calibration period in the Mediterranean MED region. For each region, the bars refer respectively to V2 (blue) and V3 (red). The geographical location of regions is displayed in the annex

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CMEMS Annual Ocean State Report

State of the global ocean and the European seas, highlighting changes occurred during the previous year. Value added information based on CMEMS products (reprocessing, reanalysis) and scientific expertise. Published in a peer-reviewed journal (Journal of Operational Oceanography).

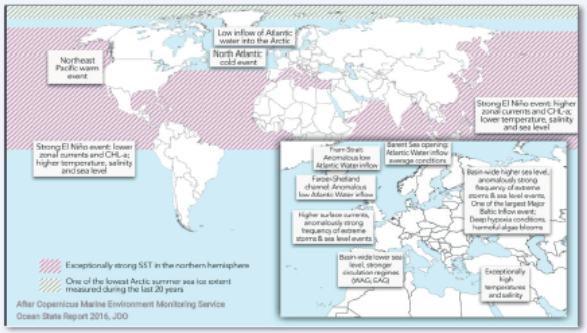
Written by 80 scientific experts from more than 25 European institutions, the first Ocean State Report is a step forward into the development of regular annual reporting on the state and health of the global ocean and European regional seas based on Copernicus Marine Environment Monitoring Service products.

This document is a comprehensive summary of the Copernicus Marine Service "Ocean State Report" and aims at providing its major findings.

PRINCIPAL FINDINGS

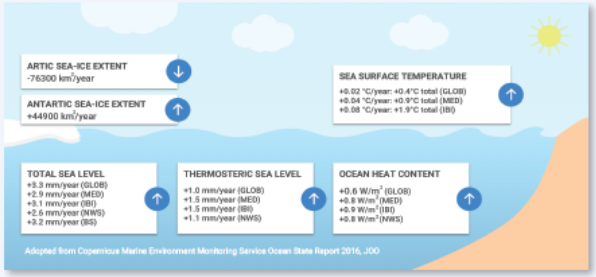
Principal findings of the first Ocean State Report focus on the fundamental role of the oceans in the Earth's climate system; as an energetic and biogeochemical buffer affecting the ocean's physics and chemistry; and as regulator through its ability to absorb and transport large quantities of heat, moisture, and biogeochemical gases around the planet.

Changes in 2015



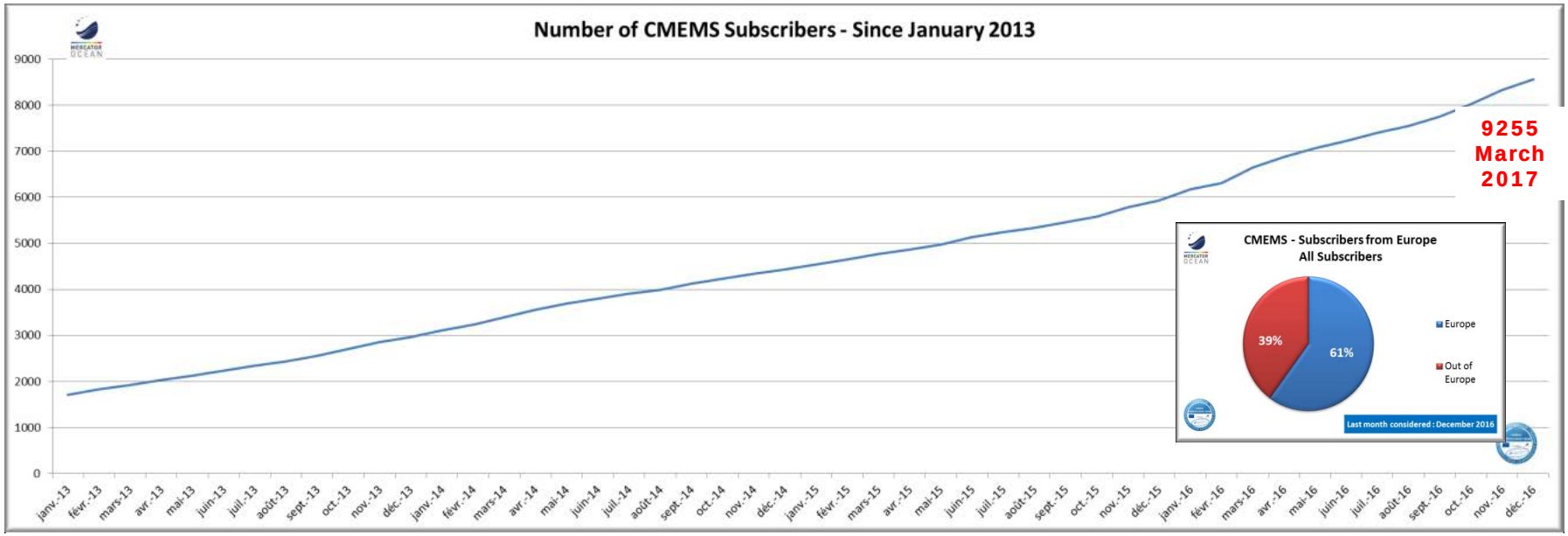
Anomalous changes are reported for the year 2015 relative to the reference period 1993-2014, using parameters such as ocean temperature and salinity, sea level, ocean heat, sea ice extent, chlorophyll and oxygen.

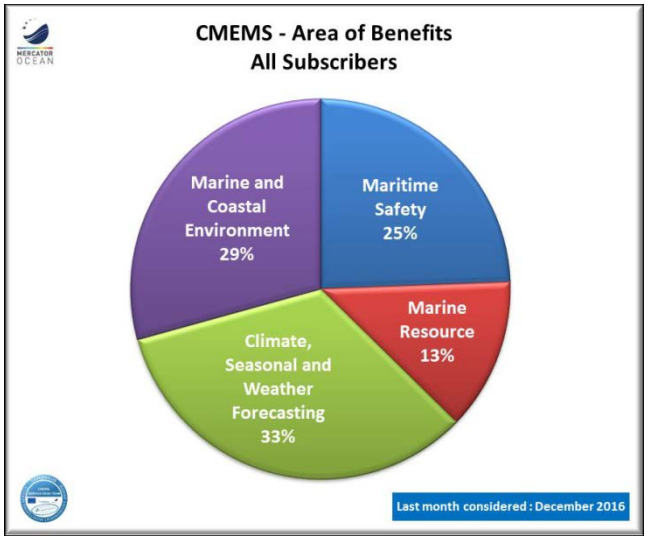
1993-2015 trends

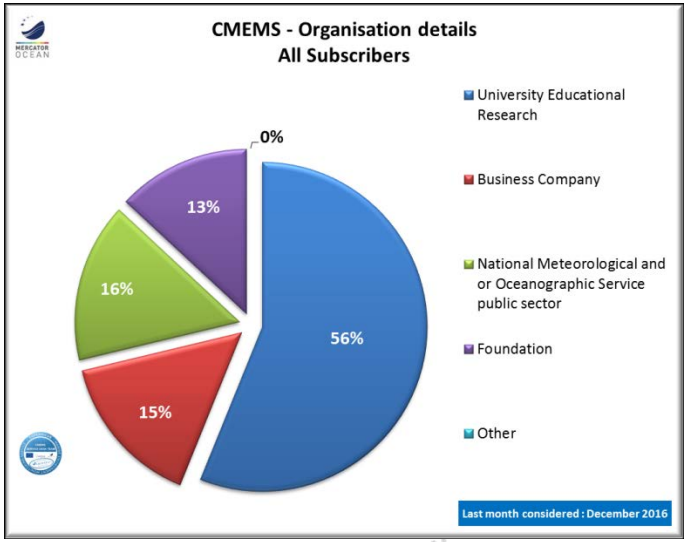


The first issue reports on a number of trends, including decreasing Arctic and increasing Antarctic sea ice extent, global and regional sea level rise, sea surface temperature rise and the warming of the global and European regional seas.

CMEMS Subscribers







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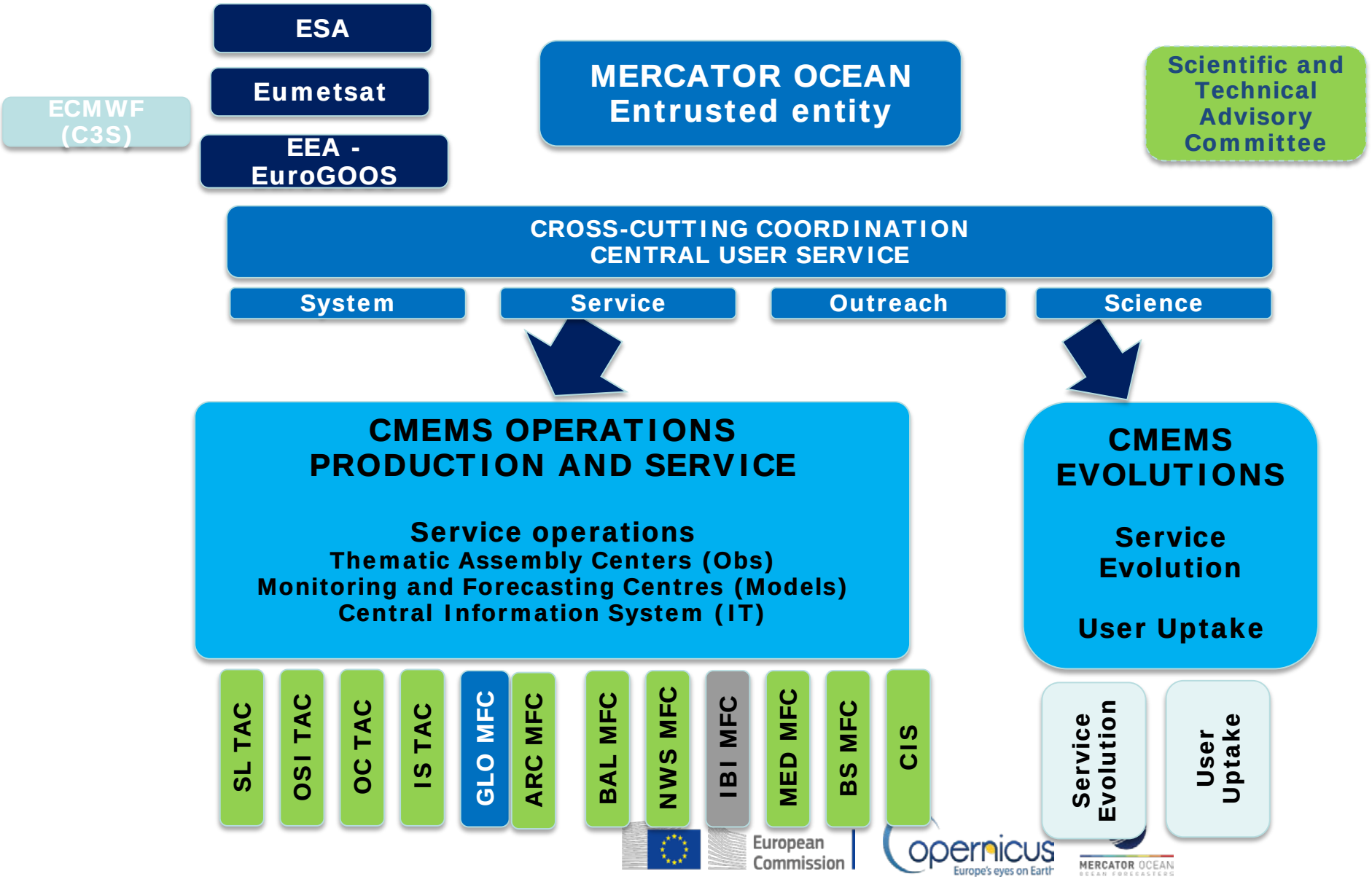
Copernicus Marine Service organisation



Copernicus Marine Service

Monitoring of the « green » ocean

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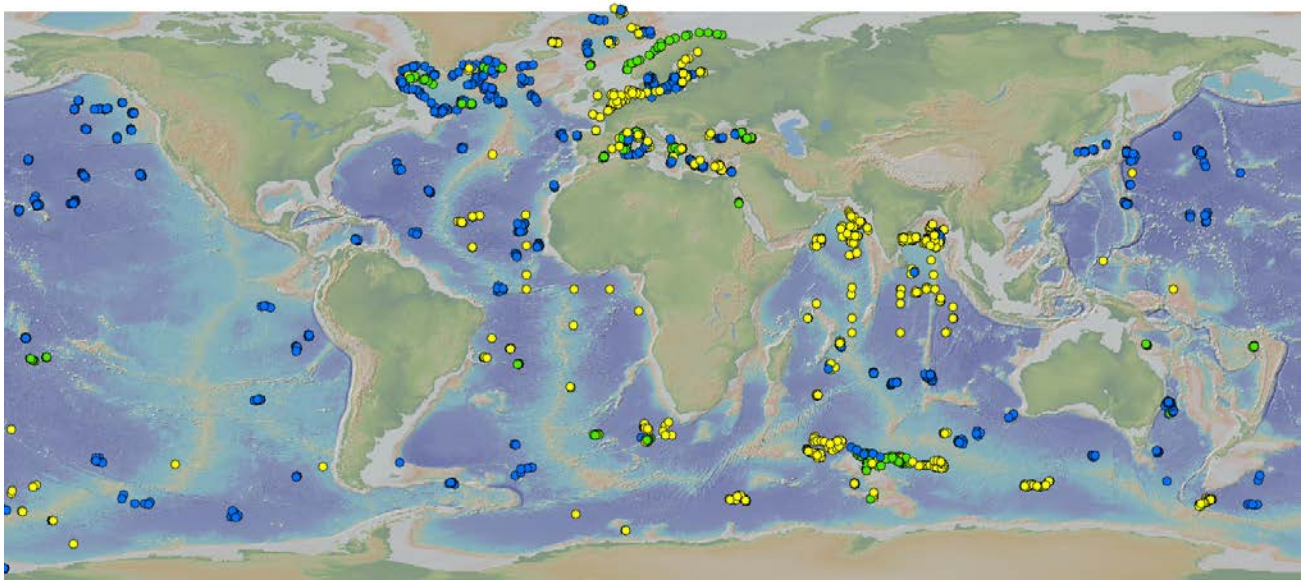
Biogeochemical In Situ data (In-Situ TAC)

In Situ observations from CMEMS in-situ Thematic Assembly Center (TAC)

- ~ 5% of the 22000 platforms that are collecting every month measure BGC parameters
- Variables: Chla, Oxygen, BBP, CDOM, PAR (NO3, pH)
- Catalogue:
  - NRT (near real time) product: mainly automatic platforms. Automatic QC
  - REP (reprocessed) product: covering 1990 – 2015, low amount of observations in Global Ocean before BGC floats. More historical data in marginal seas.



Map of BGC in situ obs. : Oxygen, Chlorophyll, Others

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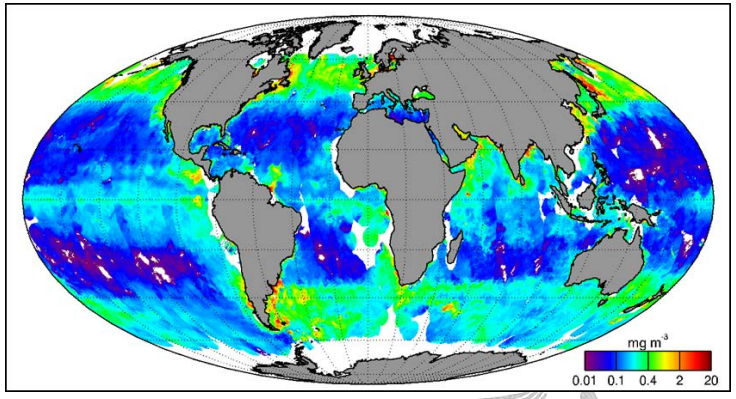
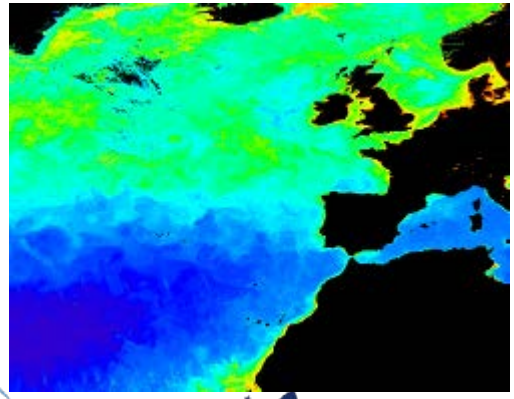
Biogeochemical Satellite data

Satellite observations from CMEMS Ocean Color TAC

- ★ Variables: Chla, BBP, attenuation coef., reflectance
- ★ Catalogue:
  - L3 & L4 global and regional single/multi sensors products
  - Sensors: Seawifs, Meris, Modis, VIIRS, OLCI (will be released in mid 2017)
  - Global REP & NRT products at 4 km resolution, (REP:1997-Aug-2016 period)
  - Regional REP & NRT products at 1 km resolution
- ★ Use of OC products:
  - For modelling quality assessment
  - For data assimilation
  - Indicators to monitor the marine environment (eg. MSFD) for the management of marine resources





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Biogeochemical Models (MFC)

Global Ocean

Variables: Chla, NO3, PO4, Si, Fe, O2, Phyto. Biomass, Primary Production

Catalogue:

Features	Near Real Time NRT	Common	Reanalysis/Hindcast RAN
BGC Model:		PISCES	
Resolution:		¼° (~25km)	
Vertical levels:	50 levels		75 levels
Time coverage:	2012 – Present		1998 -2014
Atm. Forcings:	ECMWF analyses		ERA-Interim
Ocean dyn.:	NEMO NRT 001_024		NEMO Free RAN 001_025
Assimilation:	Phy: SST, SLA, In Situ T&S		No assimilation
Assimilation scheme:	SEEK and bias correction		
Coupling BGC-Phys:		Offline, daily freq.	
Outputs:	Weekly mean		Monthly mean

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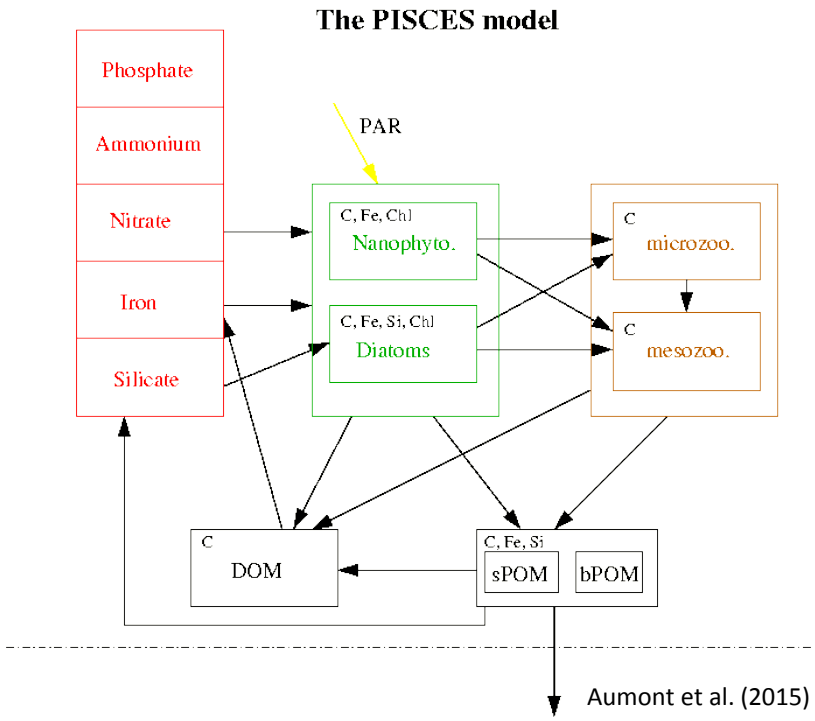
The PISCES model

Global Ocean



Basic Features

- ✓ PISCES = ecosystem model of the low trophic levels embedded in a model of ocean circulation
- ✓ 24 prognostic variables, 5 limiting nutrients, 2 phytoplankton and zooplankton species, 3 detritus compartments
- ✓ Ocean dynamics (mostly vertical transport) put together/split nutrients and light (inversely distributed in the water column) which allow phytoplankton to do photosynthesis

Community model
Available on the NEMO platform:
http://www.nemo-ocean.eu/

Advanced features

- ➢ Redfieldian model for C/N/P ratio
- ➢ variable C / Chl, C/Fe, C/Si ratios
- ➢ Carbon and oxygen cycles
- ➢ No feedback of chlorophyll concentration on temperature profile

- ➢ Mixed Monod/Quota model (Monod, 1942): no diurnal cycle
- ➢ Balance between external inputs and losts in the sediments after particule sinking
- ➢ External inputs: rivers (Fe, Si, and P), dust (Fe, Si and P) and sedimentary iron

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Biogeochemical Models (MFC)

Regional / Med Sea

Variables: Chla, NO3, PO4, O2, Phyto. Biomass, pH, pCO2

Catalogue:

Features	NRT	Common	RAN
BGC Model:		**BFM**	
Resolution:		1/16° (6 km)	
Vertical levels:		72 levels	
Time coverage:	2013 – Present		1999 – 2014
Atm. Forcings:		Med. product	
Ocean dyn.:	NEMO NRT 006_001		NEMO RAN 006_009
Assimilation:		SST, SLA, In Situ T&S, **OC Chl**	
Assimilation scheme:		3D-Var	
Coupling BGC-Phys:		Online	
Outputs:	Daily mean		Monthly mean

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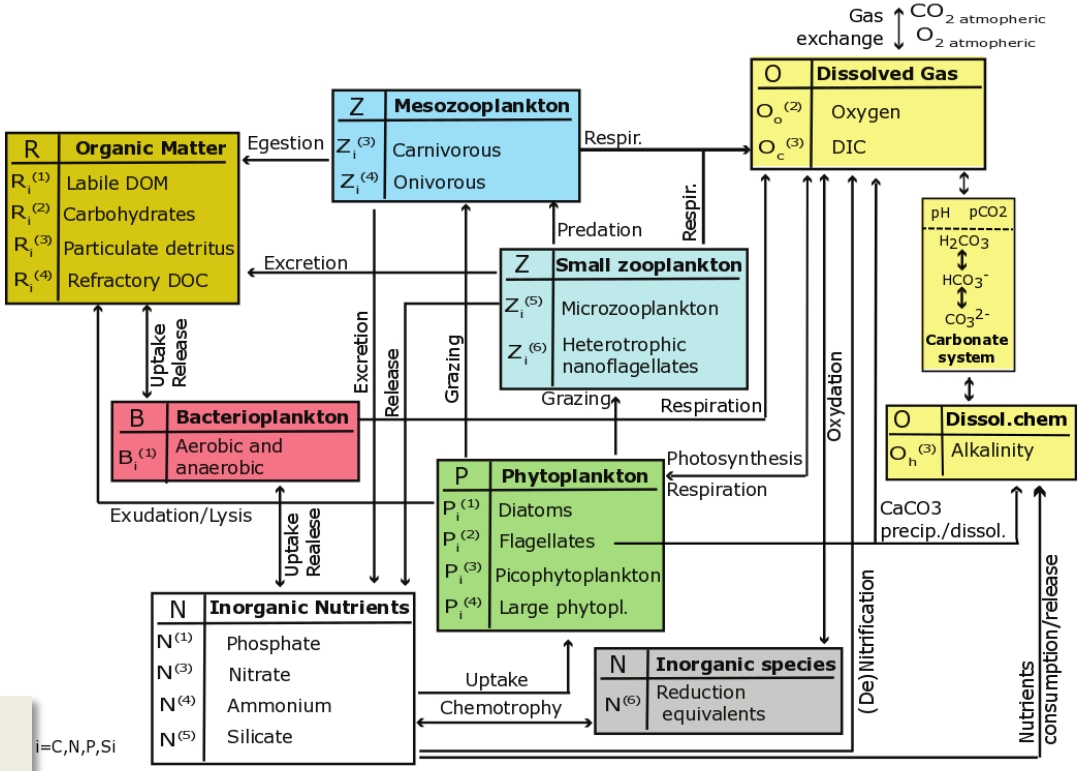
Biogeochemical Models (MFC)

Med. Sea: BFM

Features

- 51 variables;
- Cycle of C, N, P, Si, O;
- Carbonate system
- Plankton Functional Types formulation
- 4 phytoplankton & 4 zooplankton species, 1 bacteria
- Variable stoechiometry



Community model
Available on the BFM platform:
http://bfm-community.eu/

Status on CMEMS BGC Data Assimilation developments

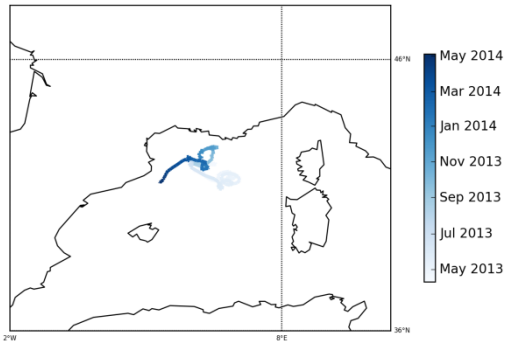
Already implemented | Work in Progress | None

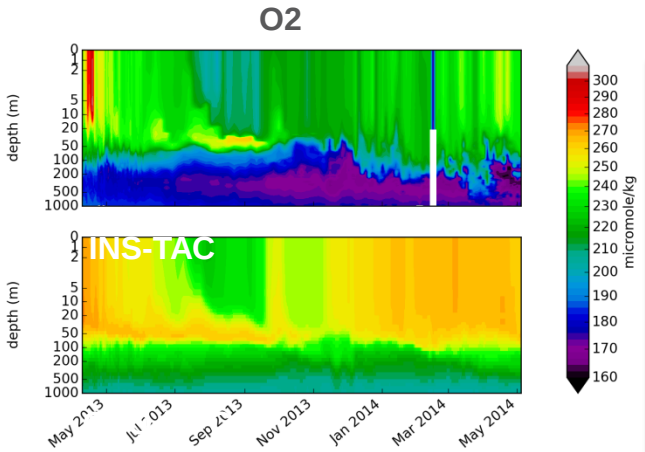
For most MFCs, BGC DA is an ongoing work, with various progress stages according to the different working groups.

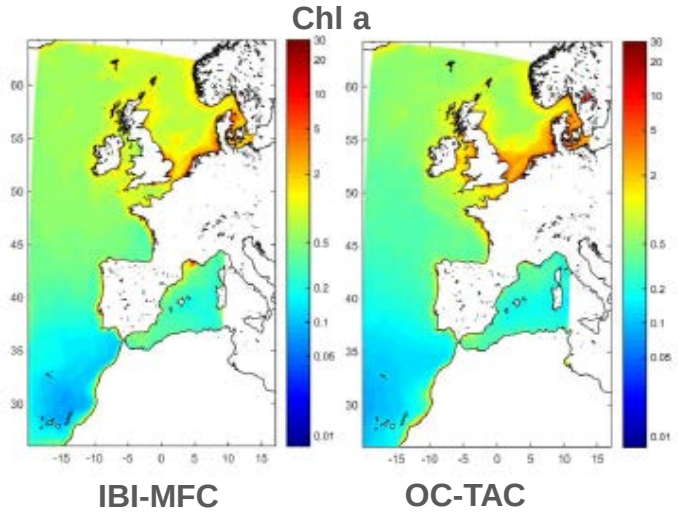
ARC-MFC	**Configuration**	**HYCOM (physic) + online ECOSMO (BGC) 12.5km, RAN at 30 km**
	NRT	no DA
	RAN	2007-2010 **with OC DA** in NORWECOM (Simon *et al.* 2015) 2007-2014 **with OC DA** in ECOSMO (ongoing)
	Work in Progress	Adaptation of DA tunings were necessary during integration because changes of OC obs properties on the period
BAL-MFC	**Configuration**	**HBM (physic) + online ERGOM (BGC) 1nm, RAN at 2nm**
	NRT	no DA
	RAN	DA of nutrient profiles (N, P, O) ➔ ends in 1999, no longer disseminated
BS-MFC	**DA is not implemented so far**	
IBI-MFC	**Configuration**	**NEMO 1/36° + PISCES at 1/12°.**
	NRT / RAN	no DA - DA is not expected to be implemented so far
GLO-MFC	**Configuration**	**¼° NEMO (physic) + offline PISCES (BGC) global model at ¼° - Weekly products**
	NRT / RAN	No current DA
	Work in Progress	Implementation of **assimilation of satellite surface Chla** at global scale – SAM2 Reduced Order Kalman Filter
MED-MFC	**Configuration**	**BFM model at 1/16°**
	NRT / RAN	**DA of Chla** in pelagic area (z>200m) estimates from MODIS satellite data from OC TAC ESA CCI ocean color observation are assimilated in the RAN
	Method	3DVar
NWS-MFC	**Configuration**	**NEMO + ERSEM**
	NRT / RAN	no DA
	Work in Progress	Assimilation of Chl-a already done at UK-MetOffice with FOAM (Hemming et al., 2008), adaptation currently going on for NWS

Validation&Quality assessment

- Common work concerning validation with new sensors/instruments (e.g. BGC Argo, Ferry-Boxes, Moorings)
- Validation/Verification/Qualification and Performance assessment of the operational centres are performed for:
  - Chl against in-situ and satellite data, climatologies
  - NO3, PO4, Si, O2 against in-situ data, climatologies
  - DIC, Alkalinity against climatologies
- Monitor performance on key physical parameters for BGC variables (e.g. MLD)







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Applications for marine resources management

Production of key ecosystem variables (zooplankton and micronekton) using CMEMS products and application to exploited fish population population dynamics (CLS)

Monitoring of pelagic habitats in support of high trophic level modelling and fisheries management (JRC)

Services for Aquaculture in the Mediterranean Sea (ACRI)

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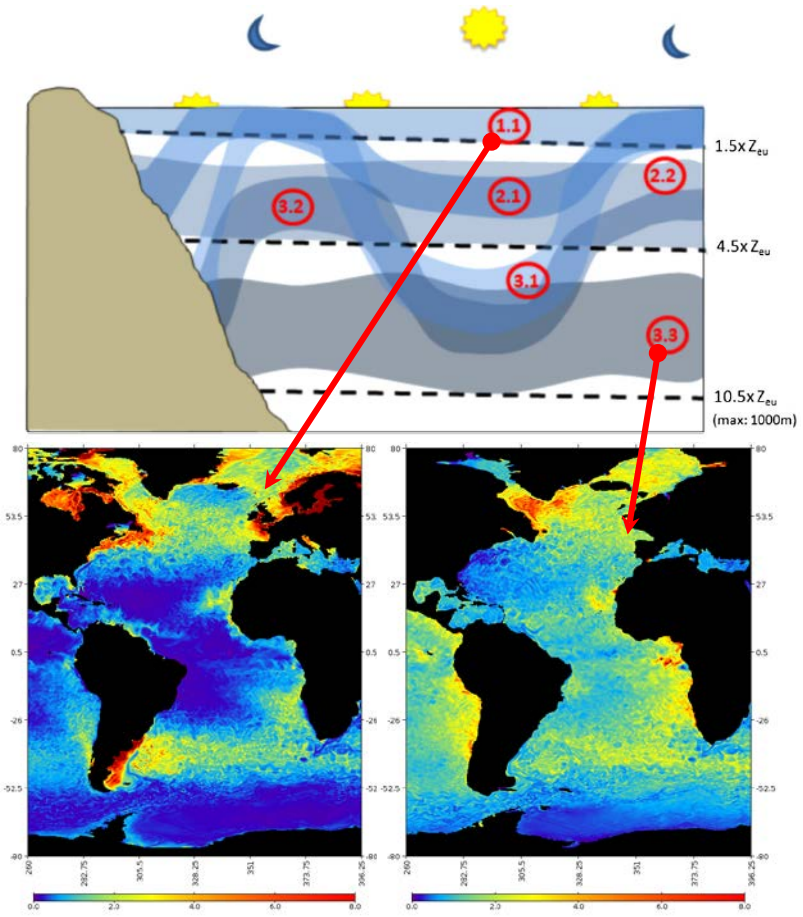
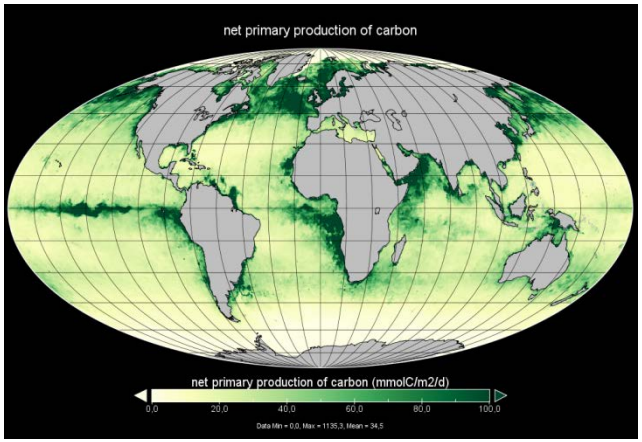
Use of CMEMS products to force the SEAPODYM model. SEAPODYM includes mid-trophic functional groups (zooplankton & micronekton) representing the intermediate levels of the oceanic food web and detailed fish population dynamics (P. Lehodey, CLS)



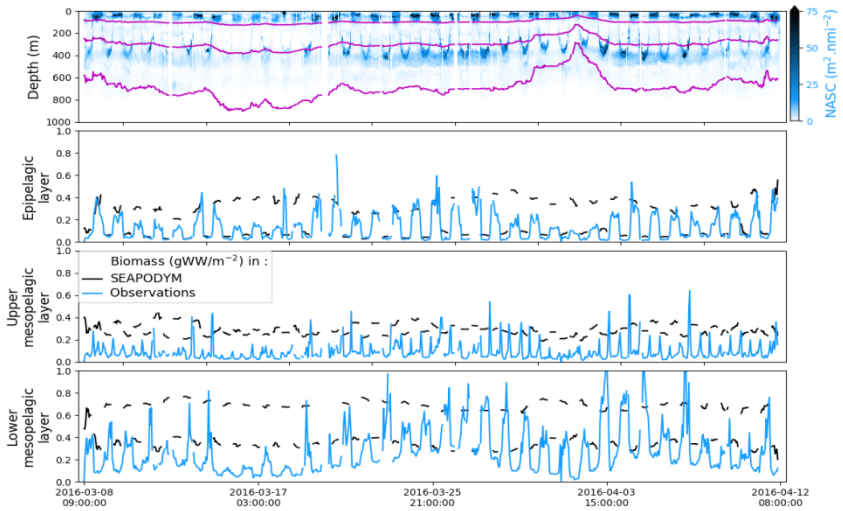
One zooplankton and 6 micronekton functional groups between surface and ~1000m depth with PP as the energy source, and temperature and currents driving the dynamics.

The model requires ocean temperature, currents and Primary production (PP) as forcing



PP is provided by biogeochemical models or derived from satellite Ocean colour data

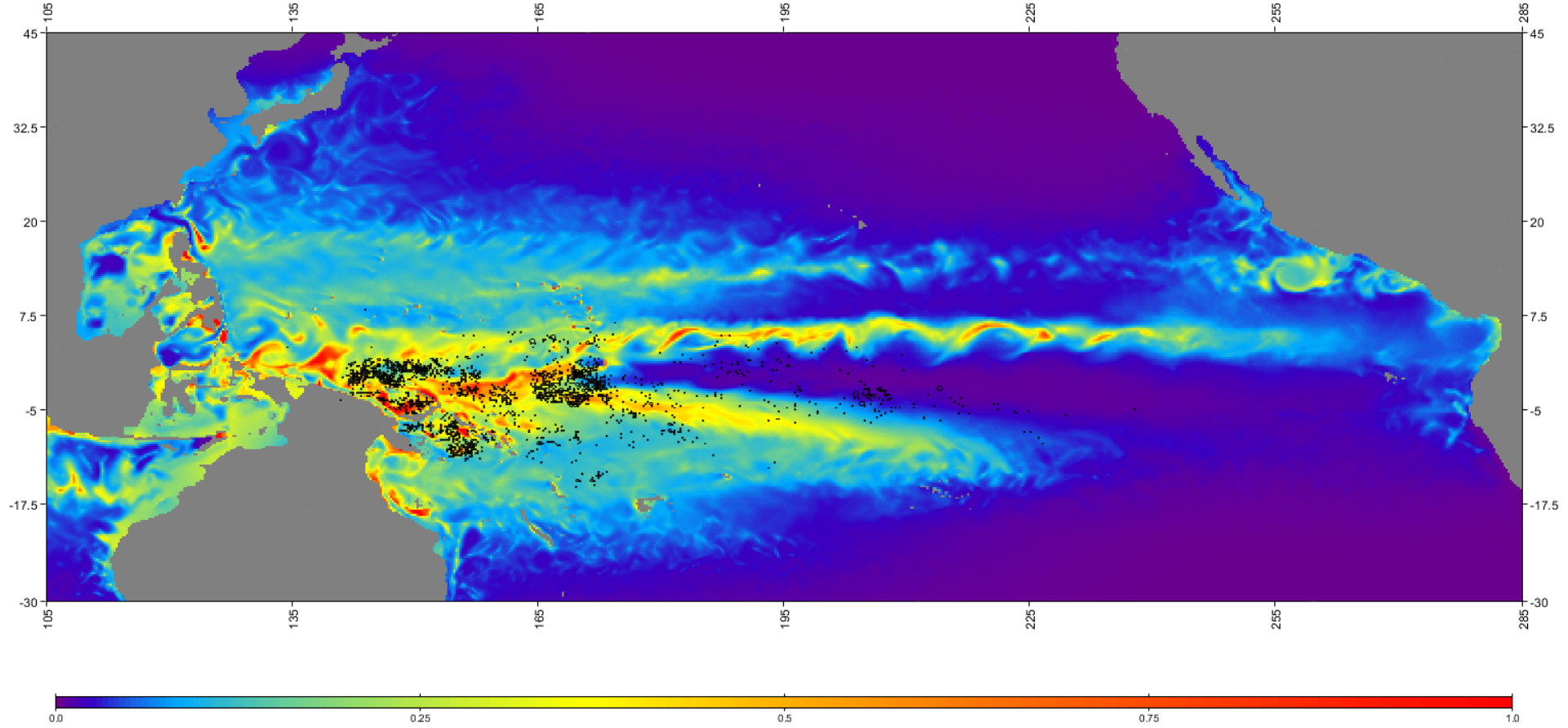
Zooplankton and micronekton outputs are optimized (model parameters) and validated (model outputs) using in situ data (zooplankton net sampling and bio-acoustic transects (38kHz)



Validation after downscaling of optimized parameters at resolution ¼° x week using GLORYS2v4 (free run)

Predicted exploitable (30-70 cm FL) skipjack density (t/km^2) at resolution ¼° x week (2013-2015) and observed total catch (monthly)

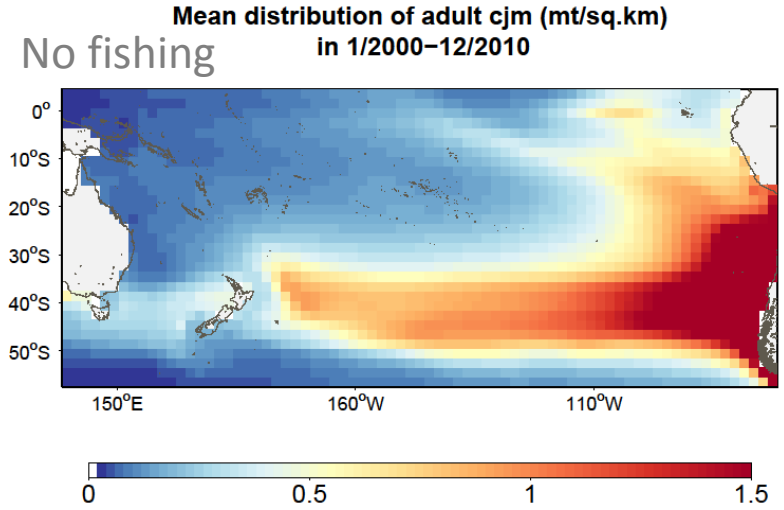
P. Lehodey, CLS

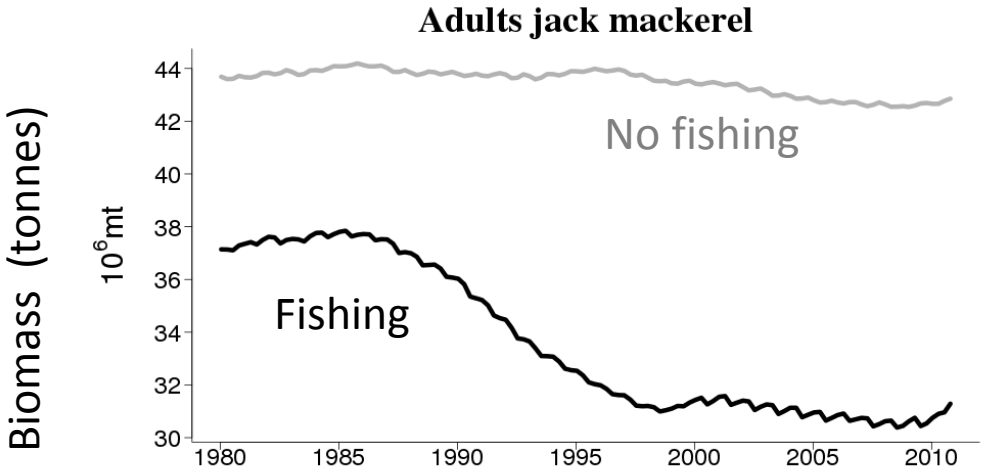


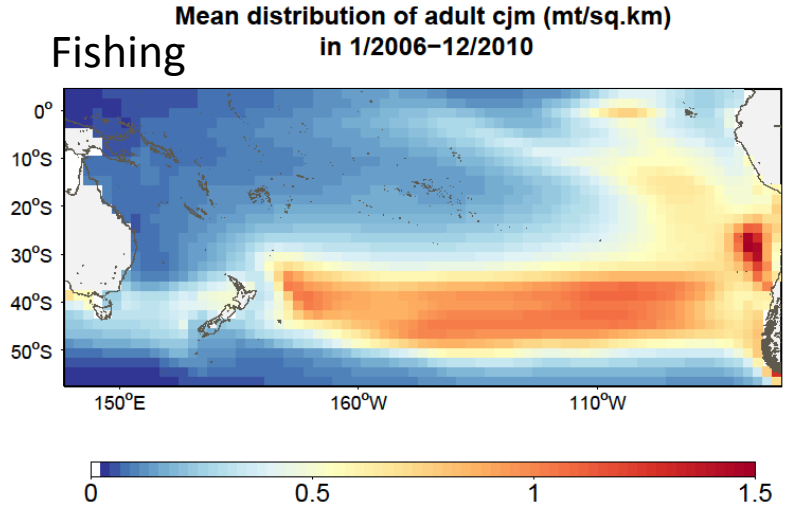
Since the 1970's, South Pacific jack mackerel (*Trachurus murphyi*) is one of the world's most important commercial exploited fish stock.

Hindcast simulation of coupled NEMO-PISCES physical-biogeochemical models provides historical data set of environmental variables (temperature, currents, primary production, dissolved oxygen) needed to run a fish population dynamics model to estimate stock and fishing impact.

P. Lehodey, CLS







Dragon et al., in press. Modelling South Pacific Jack Mackerel spatial population dynamics and fisheries. *Fisheries Oceanography.*

Forecasting and management center for marine resources

INDESO

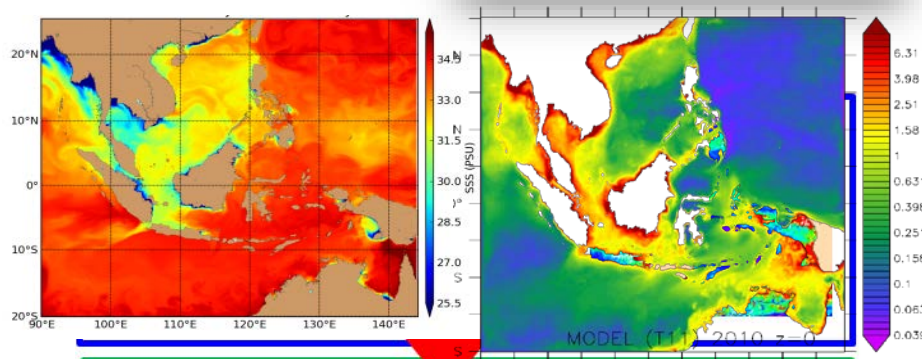
CLS
COLLECTE LOCALISATION SATELLITES

Objectives

- Predict changes in fishery resource
- Protect them from illigal fishing
- Develop the fish stock on a sustainable way

The Numerical models suite consists of :

- ✓ **Physics (Mercator Ocean and CMEMS)**
- ✓ **Biochemistry (Mercator Ocean and CMEMS)**
- ✓ **Fish population dynamics (from CLS)**



SEAPODYM : prey + predator population dynamics model

The suite of models :

→ Fully operational in Perancak (Bali) since September 2014

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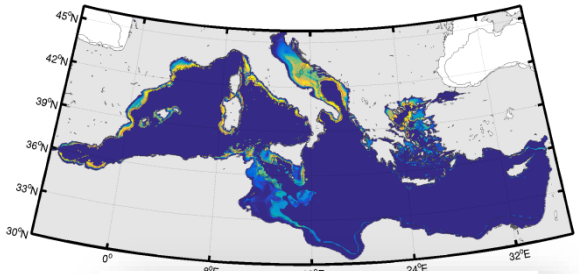
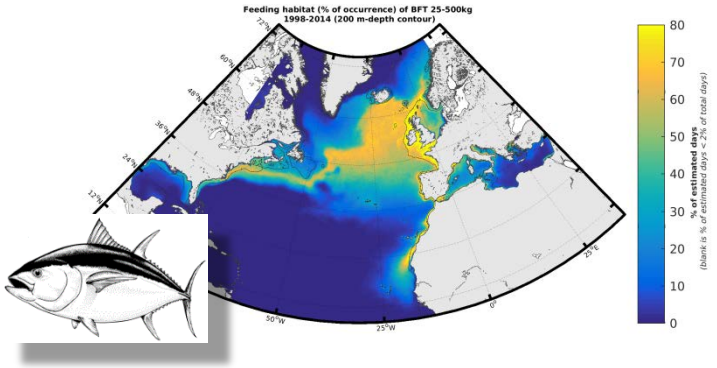
Core feeding habitat of marine species:
Daily satellite chl-a+physics from EU Copernicus Marine Service

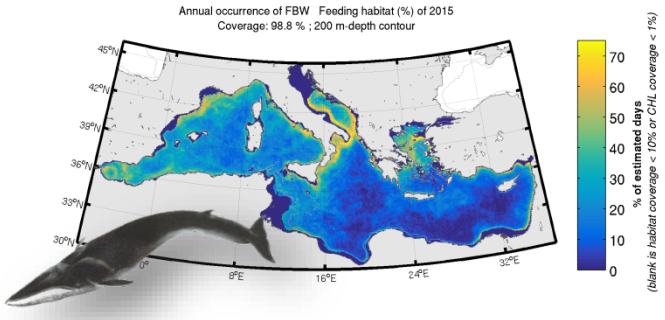
Hake nurseries *(Druon et al 2015)*



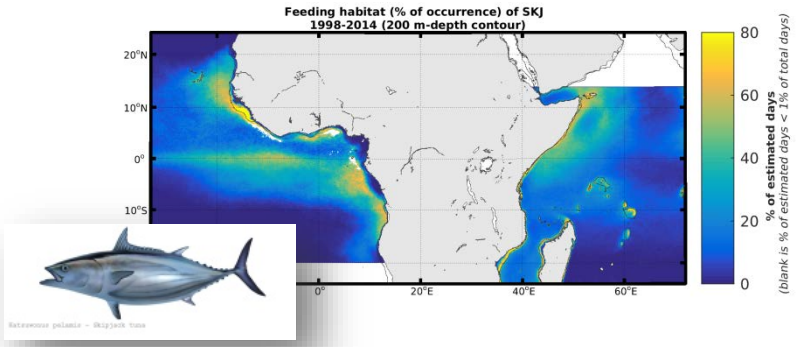
Atlantic bluefin tuna (*Druon et al 2016*)



Fin whale *(Druon et al 2012)*



Skipjack tuna *(Druon et al 2016)*



J.N. Druon, Joint Research Center

Monitoring of pelagic habitats in support of high trophic level modelling and fisheries management

European Commission

REAL-TIME AVOIDANCE OF HAKE NURSERIES

Operational Mitigation of Juvenile by-catch

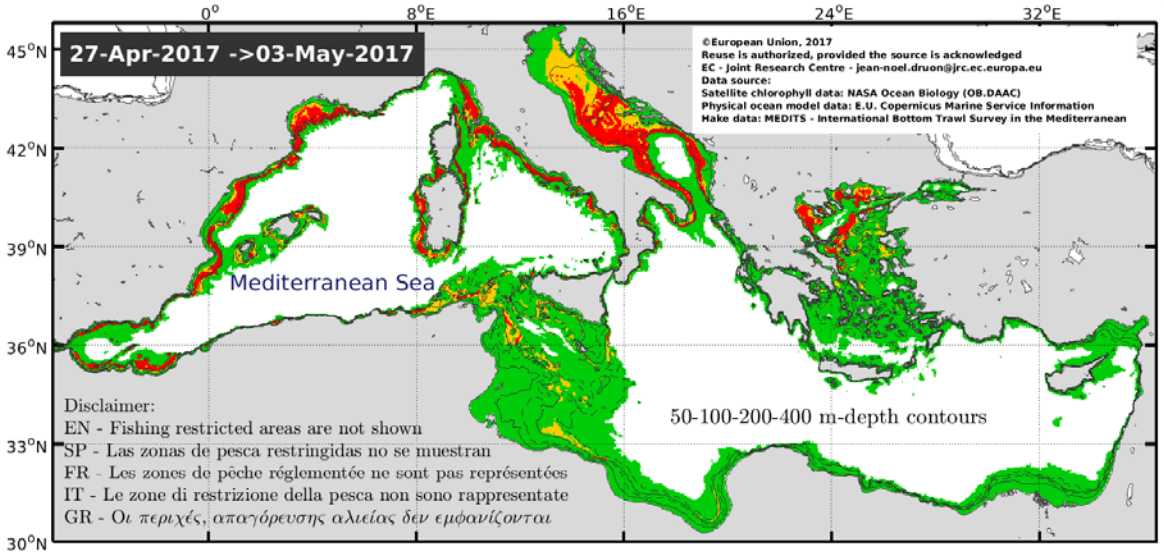
(daily update at 16.00 Central European Time)

Real-time mapping of bottom trawling preferable avoidance

based on habitat estimation of hake nurseries (Druon et al. 2015)

http://fishreg.jrc.ec.europa.eu/fish-habitat

EN - Bottom trawling avoidance areas derived from hake nurseries potential distribution (0-1000 m)
SP - Zonas de arrastre de fondo a evitar derivadas de la distribución potencial de las áreas de cría de merluza (0-1000 m)
FR - Zones de chalutage de fond *à* éviter établies depuis la distribution potentielle des nourriceries de merlu (0-1000 m)
IT - Zone a strascico di fondo da evitare stabilite dalla distribuzione potenziale dei giovanili di nasello (0-1000 m)
GR - *Περιοχές αποφυγής αλιείας μηχανότρατας, με βάση τα πιθανά νηπιακά πεδία του μπακαλιάρου* (0-1000 m)



EN - Bottom trawling: Preferable area / Preferable avoidance/ Absolute avoidance
SP - Arrastre de fondo: Zona preferible / A evitar preferiblemente/ A evitar absolutamente
FR - Chalut de fond: Zone préférentielle / A éviter préférablement / A éviter absolument
IT - Strascico a fondo: Zona preferibile / Da evitare preferibilmente / Da evitare assolutamente
GR - *Μηχανότρατα: Επιθυμητή περιοχή / Επιθυμητό να αποφεύγεται / Να αποφεύγεται παντελώς*

Downloa

EN: Dow

IT: Scar

FR: Télé

Send to
formats.
Visualize animation for:

- daily variability (.gif),
- monthly variability (.gif),

European Commission

Suporting Aquaculture and Fisheries Industries in the Mediterranean Sea

SAFI Indicators

Bathymetry for shallow waters	Sentinel-2
Sea Surface Temperature Fronts	SST
Harmful Algal Bloom Detection	Ocean Colour
Mussel Farming Site Selection	Ocean Colour, SST, met
Mussel Growth Indicators	Ocean Colour, SST, met
Salmon Aquaculture Site Selection	Ocean Colour, SST
Sea Bass/Sea Bream Aquaculture Site	Ocean Colour, SST, met
Small Pelagic Spawning	SST, met
Bivalve Maturation Indicators	Ocean Colour, SST, met

OCTAC CMEMS

Use of ocean colour and Sea Surface Temperature CMEMS data to support aquaculture and fisheries industries

SAFI downstream service (ACRI) to support Aquaculture and Fisheries industries.

Free, open and sustained access, of CMEMS model outputs and satellite data. Single portal for an easy access to all products.

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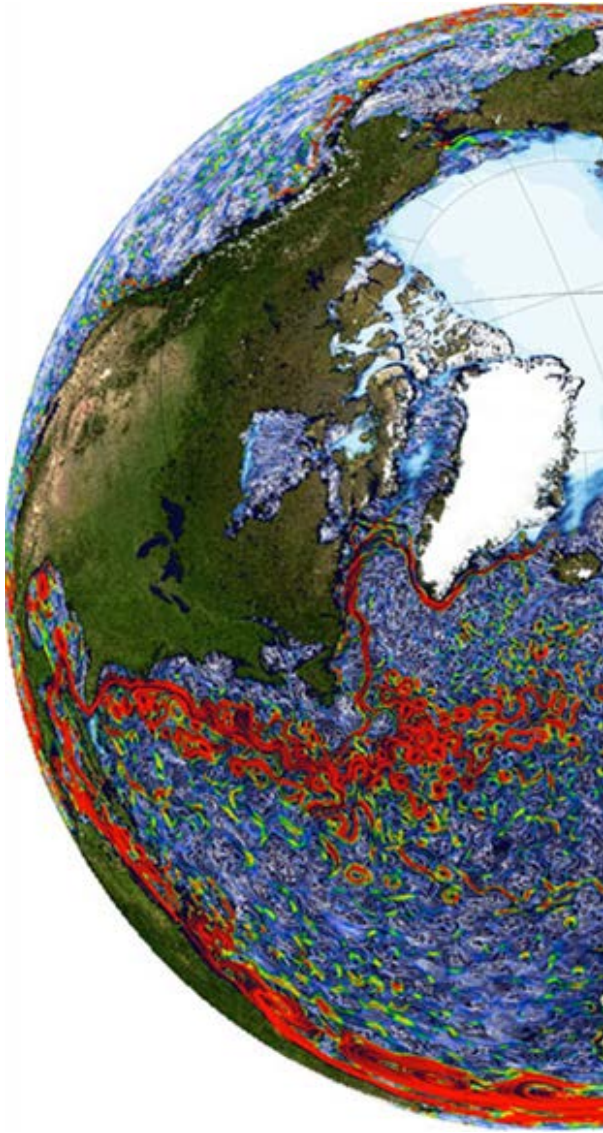
Conclusion (1)

- CMEMS is a major achievement for the development of operational oceanography in Europe.
- Open & free, validated, operational and long-term service.
- Core service : physics and biogeochemistry observation (in-situ & satellite) and modeling products, real time and multi-year (reprocessing/reanalyses).
- Has allowed the development of an increasing number of downstream applications and services.



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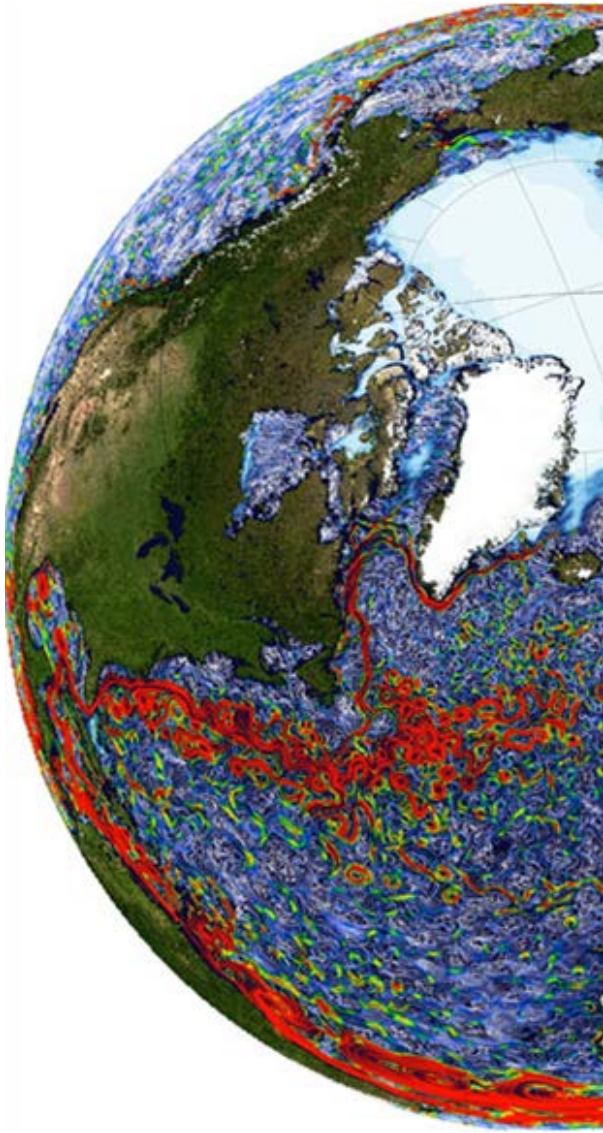
Conclusion (2)

- **Green ocean monitoring and marine resources applications**

  - Still an emerging field and application area. Requires working with intermediate & end users (e.g. agencies in charge of fish stock management, aquaculture industry). Essential role of R&D to improve the core/downstream offer (e.g. BGC modeling and data assimilation, long–term reanalyses, coastal, higher trophic level, projections).

  - Requires major improvements of the in-situ ocean observing system. Improving "green" component is key (e.g. BGC Argo, coastal observations).



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