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
Copernicus Marine Service

Organization, products & services, users and applications
The European Copernicus Programme

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

IN SITU

SERVICES

MARINE

ATMOSPHERE

LAND

SECURITY

EMERGENCY

CLIMATE
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
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
- Ocean, climate and ecosystem research
- Coastal applications, water quality, environmental monitoring and reporting/regulation, coastal hazards
- Others...
The Copernicus Marine Environment Monitoring Service

A long-term EU Marine Service:

- **Operational** and **scientificaly 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**
The Copernicus Marine Service

Observations and Models

Reprocessing Reanalyses
30 years

Real-time
Daily, hourly

Forecast
2 to 10 days

Essential Ocean Variables

Discover
View
Download
Open & Free

Observations and Models:

- Global
- Arctic
- Baltic
- NWS
- IBI
- Med Sea
- Black Sea

Reprocessing Reanalyses:
30 years

Real-time:
Daily, hourly

Forecast:
2 to 10 days

Essential Ocean Variables:

- Currents
- Sea Level
- Temperature
- Salinity
- Sea Ice
- Waves, Winds
- Biochemistry

Open & Free
SCIENTIFIC VALIDATION
METHODS / METRICS BASED ON
INTERNATIONAL STANDARDS

PRODUCT AND PRODUCT
QUALITY DOCUMENTATION FOR
ALL PRODUCTS

Copernicus Marine Service
Evaluation of product quality

Figure 23: Sea ice area (upper panel, 10^6 km²) and extent (lower panel, 10^12 km²) in the Arctic in HR global products V3 (blue line), HR global products V4 (black line) and SMOS observations (red line) for a one year period ending in June 2011

Figure 24: Comparison of GP data validation between years 2011-2012. Left: standard average (all). Right: V3 standard 16.5 month average (0.75°×0.75°) period beginning in October 2011.
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).

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

Number of CMEMS Subscribers - Since January 2013

CMEMS - Area of Benefits
All Subscribers

CMEMS - Organisation details
All Subscribers

Last month considered: December 2016

9255
March 2017
Copernicus Marine Service organisation

MERCATOR OCEAN
Entrusted entity

CROSS-CUTTING COORDINATION
CENTRAL USER SERVICE

System  Service  Outreach  Science

CMEMS OPERATIONS
PRODUCTION AND SERVICE

Service operations
Thematic Assembly Centers (Obs)
Monitoring and Forecasting Centres (Models)
Central Information System (IT)

CMEMS EVOLUTIONS
Service Evolution
User Uptake

Scientific and Technical Advisory Committee

ECMWF (C3S)
ESA
Eumetsat
EEA - EuroGOOS

SL TAC  OSI TAC  OC TAC  IS TAC  GLO MFC  ARC MFC  BAL MFC  NWS MFC  IBI MFC  MED MFC  BS MFC  CIS

Scientific and Technical Advisory Committee

EUROPEAN COMMISSION

Copernicus
Europe's eyes on Earth
Copernicus Marine Service

Monitoring of the « green » ocean
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

Map of BGC in situ obs. : Oxygen, Chlorophyll, Others
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
# Biogeochemical Models (MFC)

## Global Ocean

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

### Catalogue:

- **Near Real Time (NRT):**
  - **BGC Model:** PISCES
  - **Resolution:** $\frac{1}{4}^\circ$ (~25km)
  - **Vertical levels:** 50 levels
  - **Time coverage:** 2012 – Present
  - **Atm. Forcings:** ECMWF analyses
  - **Ocean dyn.:** NEMO NRT 001_024
  - **Assimilation:** Phy: SST, SLA, In Situ T&S
  - **Assimilation scheme:** SEEK and bias correction
  - **Coupling BGC-Phys:** Offline, daily freq.
  - **Outputs:** Weekly mean

- **Reanalysis/Hindcast (RAN):**
  - **BGC Model:**
  - **Resolution:** $\frac{1}{4}^\circ$ (~25km)
  - **Vertical levels:** 75 levels
  - **Time coverage:** 1998 - 2014
  - **Atm. Forcings:** ERA-Interim
  - **Ocean dyn.:** NEMO Free RAN 001_025
  - **Assimilation:** No assimilation
  - **Assimilation scheme:**
  - **Coupling BGC-Phys:**
  - **Outputs:** Monthly mean

[European Commission and Copernicus Logos]
The PISCES model

Global Ocean

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

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/

- 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
## Biogeochemical Models (MFC)

### Regional / Med Sea

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

**Catalogue:**

<table>
<thead>
<tr>
<th>Features</th>
<th>NRT</th>
<th>Common</th>
<th>RAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>BGC Model:</td>
<td></td>
<td><strong>BFM</strong></td>
<td></td>
</tr>
<tr>
<td>Resolution:</td>
<td>1/16° (6 km)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical levels:</td>
<td>72 levels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atm. Forcings:</td>
<td>Med. product</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ocean dyn.:</td>
<td>NEMO NRT 006_001</td>
<td>NEMO RAN 006_009</td>
<td></td>
</tr>
<tr>
<td>Assimilation:</td>
<td>SST, SLA, In Situ T&amp;S, OC Chl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assimilation scheme:</td>
<td>3D-Var</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coupling BGC-Phys:</td>
<td>Online</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outputs:</td>
<td>Daily mean</td>
<td>Monthly mean</td>
<td></td>
</tr>
</tbody>
</table>
Biogeochemical Models (MFC)

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/
<table>
<thead>
<tr>
<th>MFC</th>
<th>Configuration</th>
<th>HYCOM (physic) + online ECOSMO (BGC) 12.5km, RAN at 30 km</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ARC-MFC</strong></td>
<td>NRT</td>
<td>no DA</td>
</tr>
<tr>
<td></td>
<td>RAN</td>
<td>2007-2010 with OC DA in NORWECOM (Simon et al. 2015)</td>
</tr>
<tr>
<td></td>
<td>Work in Progress</td>
<td>Adaptation of DA tunings were necessary during integration because changes of OC obs properties on the period</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2007-2014 with OC DA in ECOSMO (ongoing)</td>
</tr>
<tr>
<td><strong>BAL-MFC</strong></td>
<td>NRT</td>
<td>no DA</td>
</tr>
<tr>
<td></td>
<td>RAN</td>
<td>DA of nutrient profiles (N, P, O) → ends in 1999, no longer disseminated</td>
</tr>
<tr>
<td><strong>BS-MFC</strong></td>
<td></td>
<td><strong>DA is not implemented so far</strong></td>
</tr>
<tr>
<td><strong>IBI-MFC</strong></td>
<td>Configuration</td>
<td>NEMO 1/36° + PISCES at 1/12°.</td>
</tr>
<tr>
<td></td>
<td>NRT / RAN</td>
<td>no DA - DA is not expected to be implemented so far</td>
</tr>
<tr>
<td><strong>GLO-MFC</strong></td>
<td>Configuration</td>
<td>⅛° NEMO (physic) + offline PISCES (BGC) global model at ⅛° - Weekly products</td>
</tr>
<tr>
<td></td>
<td>NRT / RAN</td>
<td>No current DA</td>
</tr>
<tr>
<td>Work in</td>
<td>Work in Progress</td>
<td>Implementation of assimilation of satellite surface Chla at global scale – SAM2 Reduced Order Kalman Filter</td>
</tr>
<tr>
<td><strong>MED-MFC</strong></td>
<td>Configuration</td>
<td>BFM model at 1/16°</td>
</tr>
<tr>
<td></td>
<td>NRT / RAN</td>
<td>DA of Chla in pelagic area (z&gt;200m) estimates from MODIS satellite data from OC TAC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ESA CCI ocean color observation are assimilated in the RAN</td>
</tr>
<tr>
<td></td>
<td>Method</td>
<td>3DVar</td>
</tr>
<tr>
<td><strong>NWS-MFC</strong></td>
<td>Configuration</td>
<td>NEMO + ERSEM</td>
</tr>
<tr>
<td></td>
<td>NRT / RAN</td>
<td>no DA</td>
</tr>
<tr>
<td>Work in</td>
<td>Work in Progress</td>
<td>Assimilation of Chl-a already done at UK-MetOffice with FOAM (Hemming et al., 2008), adaptation currently going on for NWS</td>
</tr>
</tbody>
</table>

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.
• 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)
Copernicus Marine Service

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)
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).

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)).

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.
Validation after downscaling of optimized parameters at resolution $\frac{1}{4}^{\circ}$ x week using GLORYS2v4 (free run)

Predicted exploitable (30-70 cm FL) skipjack density (t/km$^2$) at resolution $\frac{1}{4}^{\circ}$ 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.

Forecasting and management center for marine resources

Objectives

- Predict changes in fishery resource
- Protect them from illegal 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)

The suite of models:

- Fully operational in Perancak (Bali) since September 2014
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
REAL-TIME AVOIDANCE OF HAKE NURSERIES

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 nurriceries de merlu (0-1000 m)
IT - Zone a strascio di fondo da evitare stabilite dalla distribuzione potenziale dei giovanili di nasello (0-1000 m)
GR - Περιοχές αποφυγής αλιείας μηχανώντρατος, με βάση τα πιθανά γεωγραφικά πεδία των μακαλάρων (0-1000 m)

Disclaimer:
EN - Fishing restricted areas are not shown
SP - Las zonas de pesca restringidas no se muestran
FR - Les zones de pêche réglementées ne sont pas représentées
IT - Le zone di restrizione della pesca non sono rappresentate
GR - Οι περιοχές, αποφυγής αλιείας δεν εμφανίζονται

Download format:
EN: Download layers as: shapefile
IT: Scarica le strati come: shapefile
FR: Télécharger les couches en: shapefile

Send to: info@fishreg.jrc.ec.europa.eu

Visualize animation for:
- daily variability (.gif),
- monthly variability (.gif),
Supporting Aquaculture and Fisheries Industries in the Mediterranean Sea

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.
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.
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).