National Report – template description

a. France – Mercator Ocean

Background

Mercator Ocean is the French center for analysis and forecasting of the global ocean, i.e. a service provider of ocean information in real and delayed time. The company is located in South-West France near Toulouse.

Mercator Ocean is a privately-owned non-profit company, funded by nine major European institutions involved in operational oceanography : CMCC (Centro Euro-Mediterraneo sui Cambiamenti Climatici, It), CNRS (National Center of Scientific Research, Fr), Ifremer (French Research Institute for Exploitation of the Sea, Fr), IRD (Institute of Research for Development, Fr), MetOffice (Uk), Météo-France (Fr), NERSC (Nansen Environmental and Remote Sensing Center, No), Puertos del Estado (Sp), SHOM (Hydrographic and Oceanographic Service of the French Navy, Fr).

The European Union delegates to Mercator Ocean the role and responsibility of managing the EU budget for delivering the COPERNICUS MARINE ENVIRONMENT MONITORING SERVICE (CMEMS) on its current multi-annual financial framework 2014-2020. The delegation agreement between the European Union, represented by the European Commission, and Mercator Ocean for setting-up the CMEMS, led and will lead Mercator Ocean to issue a range of calls for tender to create the necessary strong network of partners.

Mercator Ocean is in charge of the development, evolution and operation of the Global Monitoring Forecasting Center for CMEMS, and develops also other operational or reanalysis systems for its shareholders. Mercator Ocean is also in charge of the coordination and development of the Iberian, Biscay and Irish seas Monitoring and Forecasting Center (IBI MFC) for CMEMS.

1. Input data

Mercator Océan relies on existing observational data assembly centers to collect, to process and to validate its input data. Real time and delayed mode observations are used for data assimilation and for analysis / forecast validation and verification and include:

- *Altimetry* (SSALTO /DUACS product from AVISO data center, disseminated through CMEMS): Along-track and inter-calibrated sea level anomalies from all available satellite for the reprocessing observation period and Jason-2 & Jason-3, Cryosat 2, SARAL , S3A and S3B, weekly retrieval; Mean Dynamic Topography (also called Mean-Sea-Surface-Height) combining gravity (CHAMP, GRACE) measurements, and altimeter and in situ data (Rio et al., 2011, CNES-CLS09).
- *In-situ temperature and salinity data* (from CORIOLIS center, disseminated through CMEMS): ARGO profiling floats, XBT, CTD, TAO-TRITON/PIRATA/RAMA moorings, TSG, surface drifters, sea mammals; weekly retrieval; off line quality control at CORIOLIS and CLS. The CORA data base is also used for delayed time production.
- *Sea Surface Temperature:* Global NCEP/RTG 0,5° and OSTIA CMEMS SST product for operational assimilation; Reynolds 0.25° AVHRR-only SST product for reanalyses; OSTIA

CMEMS sea surface temperature product, Eumetsat / Météo-France SAF Ocean&Ice Atlantic high resolution SST product (10 km, daily) for routine validation.

- *Forcing data*: 3-hour analyses and forecast from ECMWF for operational forcing / ERA-Interim and ERA5 for reanalysis forcing; GEWEX and GPCP heat and fresh water flux products are used to correct ECMWF forcing during GLORYS reanalysis computation.
- *Surface velocity*, from the Global Drifter Program, collected and processed by the CORIOLIS center, only used for validation.
- *Sea level* from tide gauges: GLOSS, SHOM and ESEOO database, processed and corrected at CLS, only used for validation.
- *Sea Ice* concentration and drift from CERSAT (Ifremer) for GLORYS reanalysis and CMEMS product for the near real time global system.
- *Ocean Colour chlorophyll products from AQUA/MODIS distributed by ACRI and the global L3 products from CMEMS*

2. Data serving

Dissemination of MERCATOR products (products@mercator-ocean.fr) is made through www, Opendap, FTP tools and hard disk drives both for real-time and delayed-time and reanalyses. Specific procedures are set up for operational users requesting secured links. Mercator Océan which is the entrusted entity operating the Copernicus Marine Environment Monitoring Services (CMEMS, http://marine.copernicus.eu) is in charge of the central service desk for CMEMS and also contributes by providing ocean reanalyses, analyses and forecasts at the global scale and regional scale for both ocean physical and biogeochemical parameters. Information concerning the CMEMS users of the GLO MFC is provided on Figure 1. In Nov 2020, almost 434 regular users have downloaded global reanalysis and forecast products and 178TB of GLO MFC numerical products have been downloaded from the CMEMS portal.

Many use cases are presented on the CMEMS web site (http://marine.copernicus.eu/markets/use-cases/) providing information on the use of CMEMS products by geographical area, area of benefit, user typology and product in use.

Monthly Report - 1

Regular Users*	Active Users*	Organisations	Data Size (TB)
434 -0%	1 153 8%	540 11%	178,018 -0%
Variance Previous Month	Variance Previous Month	Variance Previous Month	Variance Previous Month

Per day

Countries*

Number of country
76 -5%
Variance Previous Month

Figure 1 : Monthly report for Nov 2020 for CMEMS users of the GLO MFC.

3. Models

Mercator Océan uses the NEMO z-coordinate primitive equation ocean code (Madec, 2008). It is coupled with the LIM2 and LIM3 Sea Ice Model from Louvain-La-Neuve with elastic-viscous-plastic rheology. The model system is also coupled with biogeochemical models (e.g. PISCES). The MFWAM wave model is used in the framework of CMEMS GLO MFC to produce real time forecast and reanalysis.

4. Assimilation method

Mercator Océan is developing a suite of assimilation tools (called "SAM" for Mercator Assimilation System) of increasing complexity. The data assimilation method currently used (SAM-2) relies on a reduced-order Kalman filter based on the Singular Evolutive Extended Kalman Filter (SEEK) formulation introduced by Pham et al. (1998). For the physical component of the ocean forecasting system, the SAM-2 version is used to assimilate altimetry, sea surface temperature, vertical temperature and salinity in situ profiles and more recently sea ice concentration in a fully multivariate manner using multivariate 3D error modes for the background error covariance matrix (Brasseur et al., 2005). It includes an adaptive error and a localization algorithm. It has been successfully implemented in all physical operational systems and is used since April 2007 (Lellouche et al., 2013). In parallel to SAM-2, a 3D-VAR bias correction algorithm for temperature and salinity is currently used in operational forecasting systems and in GLORYS and IBIRYS reanalyses (see section 9 for the description of the systems and reanalyses). The objective is to correct the slowly varying large scale temperature and salinity forecast errors due to models shortcomings (lack of resolution, missing physical parameterizations, surface forcing errors…).

This assimilation system is upgraded regularly and the main ongoing work concerns i) a 4D, smoother approach in the computation of the error covariance, ii) ensemble approach in the assimilation scheme.

5. Systems (operational)

The Mercator Océan system provides a full 3D depiction of the ocean dynamics and thermohaline circulation (T, S, currents, sea surface height, mixed layer depth…), with a high priority given to eddies. In association, the biogeochemical content of the ocean (Chl concentration, primary production, carbon, dissolved oxygen, nitrates, phosphates content) is also provided in near real time.

Information is available on a near-real-time and routine basis, by providing weekly Near-Real-Time Analysis and 2-week Forecasts; and on a Reanalysis mode (2 weeks behind real time), with data assimilation. For biogeochemical products, a one week forecast is delivered in NRT.

Each weekly ocean bulletin provides:

- Near-real-time ocean nowcasts and forecasts issued from routine assimilation and modelling runs
- Input data assessments and analysis (comparison & combination of data sets before assimilation)
- A set of predefined maps and 3D files giving a complete depiction of the ocean (http://bulletin.mercator-ocean.fr/html/welcome_en.jsp)
- Technical information on the ocean forecasting systems, including monitoring of the system and measurement of the timeliness.
- The GLO4 and GLO12 systems are also producing 10-day forecasts updated every day (i.e. using updated analysed and forecast surface atmospheric fields). BIOMER4 system performs 7-day forecasts updated on a weekly basis

6. Link to observations (e.g. Argo, GHRSST, etc.)

Most of the observations used in the operational and reanalysis systems are now provided in CMEMS in the In Situ, Ocean and Sea Ice, Sea Level and Ocean Color TACs. Few observations are still provided by other centres as for example the SST products in reprocessing mode which is provided by NOAA or the CERSAT sea ice concentration provided by Ifremer.

In 2020, several impact studies have been conducted concerning:

- An updated version of the Mean Dynamic Topography based on the new CNES/CLS 2018 MDT
- Current altimetry constellation (with more than 5 altimeters assimilated in real time in 2020) and high resolution new altimetry products
- Impact of L3 sea surface temperature and micro-wave SST observations
- Future altimetry constellation with dedicated OSSEs experiment of SWOT and large swath altimetry at global and regional scale in the context of SWOT ST and CNES partnership and the potential of European swath altimetry concepts analysed by ESA
- A new project just started in 2020 concern data assimilation of satellite sea surface velocity observations

7. Internal metrics and intercomparison plans

Recently, Mercator Ocean has developed a new monitoring tool called MoniQua (Monitoring Quality) that is regularly updated and improved. This allows displaying a lot of metrics (mainly comparison between analysis, forecast and observations) and comparison between systems (see example on Figure 2). Some developments have been made to add the statistics computed in the framework of OCEAN PREDICT intercomparison.

Figure 2: Example of Moniqua toolbox used to validate and intercompare operational analysis and forecasting system

In the framework of the GOV IV Task Team, Mercator Ocean is contributing to several activities as:

● Class 4 intercomparison: several datasets are provided by different contributors:
  - Temperature and salinity from insitu Argo profiles, SST from drifting buoys , Sea level anomaly gathered by the UK-Met
  - Sea ice concentration from AMSR2 satellite gathered by Environment Canada
  - Velocity drifting buoys from CMEMS/TAC delivery gathered by MOI

These data are uploaded every day in a GODAE scripted server hosted in US.

Each contributor can download the original data and compute their model equivalent to share this on the GODAE server. These Class 4 files are computed with global systems. Regularly, during meeting sessions, statistics and intercomparisons are provided (the last meeting was in May during OceanPredict'19). Some efforts have been made by all the participants to create a yearly bulletin that will summarize the performances of all the GODAE global systems.

● MultiModel Ensemble approach: Mercator Océan provides on a daily basis the surface parameters from the PSY3V3R3 system on the native grid.
● GOV/CLIVAR/GSOP project on ocean reprocessed products and reanalysis: Mercator Océan is providing all the ocean parameters for this intercomparison project, based on GLORYS2V3 and GLORYS2V4 ocean reanalysis. Moreover, Mercator Océan is conducting the intercomparison for Sea Level and Depth of the 20°C isotherm (D20). Global and regional metrics, as well as ensemble estimates are tested, with the objective to define ocean index for near-real time monitoring

8. Targeted users and envisioned external metrics

Targeted users of Mercator Océan systems are the Mercator Océan shareholders and their application sectors, the National and European Policy Makers, GODAE OceanView partners, Research, and Commercial applications.

Application Centers identified among the Mercator Océan partners, are e.g. SHOM for Navy applications, Météo-France for marine safety, oil spill monitoring, and seasonal forecasting (with a collaboration with ECMWF), and IFREMER for coastal and ecosystem monitoring.

If research is one of the leading applications in the scope of the Mercator Océan Science Working Team, more than 50% of the users are today outside the research field, both on the operational institutional (e.g. marine safety) and commercial (e.g. offshore) sectors.

Mercator Océan is serving an increasing number of users, in each of the different user targeted sectors, and with specific collaborations with each of them.

9. Reanalysis and Hindcasting activities

Interannual hindcasts are performed to scientifically validate the systems before their entry into service but the full time series is not systematically delivered on CMEMS portal. A 2-year long time series of hindcasts is available for the global physical and biogeochemical system and for the IBI area. Global and IBI reanalysis currently cover the altimetry period from 1993 and the time series are regularly updated (twice a year and in 2021 the update will be performed every month)

10. Computing resources

- Available computer resource :
  Global reanalysis and real time forecast are performed on Meteo-France supercomputing center, some development are performed on Mercator Ocean's own computer resources and also on ECMWF platform.
  Development of the IBI system is perform on Meteo-France supercomputing center but the real time production is manage in the framework of Copernicus Marine with a partnership with Puertos Del Estado, nologin and the Galician supercomputing center (CESGA)

- Future plans for expanding capabilities :

  In 2020 Meteo France has upgraded their computing center, the transfert into operation on the new computer is plan beginning 2021.

11. Consolidation phase and transition to operational systems (activities)

- Development plans towards operational systems
  Updated versions of the global 1/12° and the IBI36 systems are under development. They will be based on a new version of NEMO model (NEMO3.6), which will include improvement in term of data assimilation scheme (4D version of the scheme) and will assimilate new SST observations (the higher resolution L3 SST satellite observations). Same update will be included in the IBI36 system.
  The following tables (Table 1, Table 2 and Table 3) illustrate the status of the current global operational system and main evolution planned. All these products are developed in the framework of CMEMS coordinated by Mercator Ocean with strong partnerships for some systems.
  WAVE systems (real time and reanalysis) are developed in partnership with Meteo France.
  GREP (Global Reanalysis Ensemble Product) are developed in partnership with CMCC, ECMWF and MetOffice.
  MICRORYS (Micronekton reanalysis) are developed in partnership with CLS.

Table 1 : Main characteristics and recent evolutions of the global real time products and real time systems.

Product Name	Update description	CMEMS Version/Date of EIS
GLO12v3 GLOBAL_ANALYSIS_FORECAST_PHY_001_024	GLOBAL 1/12° physical forecasting system SMOC (Surface and Merged Ocean Currents) products in 2019	v201904

GLO12v3 GLOBAL_ANALYSIS_FORECAST_PHY_001_024	GLOBAL 1/12° physical forecasting system Update of the description with SMOC information	v201907
GLO12v3 GLOBAL_ANALYSIS_FORECAST_PHY_001_024	GLOBAL 1/12° physical forecasting system Assimilation of sentinel-3B	May 15th 2019
GLO12v3 GLOBAL_ANALYSIS_FORECAST_PHY_001_024	GLOBAL 1/12° physical forecasting system New dataset over global ocean is produced at Mercator-Ocean (Toulouse, France). It provides 3D physical fields at 1/12 degree and on 50 vertical levels for potential temperature, salinity and currents every 6 hours. Outputs instantaneous fields are interpolated on a standard regular grid in NetCDF-4 format.	202003
BIO4v1 GLOBAL_ANALYSIS_FORECAST_BIO_001_014	GLOBAL 1/4° biogeochemical forecasting system Retired product / superseded by GLOBAL_ANALYSIS_FORECAST_BIO_001_028	v201907
BIO4v2 GLOBAL_ANALYSIS_FORECAST_BIO_001_034	GLOBAL 1/4° biogeochemical forecasting system New NRT biogeochemical system including ocean color data assimilation	v201907
WAVEv2 GLOBAL_ANALYSIS_FORECAST_WAV_001_027	GLOBAL 1/12° wave forecasting system Updated IFS cycle (41) Forecasts extended to +10 days Additional satellites in assim	v202012

Table 2 : Main characteristics and recent eveolutions of the global physical multi-year products and reanalysis systems.

Product Name	*Update description*	CMEMS Version/Date of EIS
GLORYS2v4 GLOBAL_REANALYSIS_PHY_001_025	GLOBAL 1/4° physical reanalysis Global ¼° physical reanalysis not update anymore	February 14th 2019

GREPv1 GLOBAL_REANALYSIS _PHY_001_026	GLOBAL 1° physical ensemble multi system reanalysis Time serie updated to 2017	v201904
GREPv1 GLOBAL_REANALYSIS _PHY_001_026	GLOBAL 1° physical ensemble multi system reanalysis Addition of ice	v201904
GREPv1 GLOBAL_REANALYSIS _PHY_001_026	GLOBAL 1° physical ensemble multi system reanalysis The year 2018 has been processed and is now available	v202007
GREPv1 GLOBAL_REANALYSIS _PHY_001_026	GLOBAL 1° physical ensemble multi system reanalysis Time series extended to June 2019. Ongoing switch to ERA5 forcing	v202012
GREPv2 GLOBAL_REANALYSIS _PHY_001_031	GLOBAL 1/4° physical ensemble multi system reanalysis New product. High resolution (1/4°) and high frequency (daily) multi system reanalysis	v201907
GREPv2 GLOBAL_REANALYSIS _PHY_001_031	GLOBAL 1/4° physical ensemble multi system reanalysis Removed product Reanalysis over global ocean at ¼ degree and on 50 vertical levels. Usage of product GLOBAL_REANALYSIS_PHY_001_031 (in datasets: global-reanalysis-phy-001-031-daily and -monthly) is recommended as it contains same fields as in the retired product (cf. associated PUM for variables name).	v202003
GREPv2 GLOBAL_REANALYSIS _PHY_001_031	GLOBAL 1/4° physical ensemble multi system reanalysis The year 2018 has been processed and is now available	v202007
GREPv2 GLOBAL_REANALYSIS _PHY_001_031	GLOBAL 1/4° physical ensemble multi system reanalysis Time series extended to June 2019. Ongoing switch to ERA5 forcing.	v202012
GLORYS12v1 GLOBAL_REANALYSIS _PHY_001_030	GLOBAL 1/12° physical reanalysis Extend time serie to 2018.	v201907
GLORYS12v1 GLOBAL_REANALYSIS _PHY_001_030	GLOBAL 1/12° physical reanalysis Time series now extends up to 25/06/2019. Switch to ERA5 forcing flux from 26/12/2018	V202012
WAVERYSv1 GLOBAL_REANALYSIS _WAV_001_032	GLOBAL 1/4° wave reanalysis First release of Wave Reanalysis (covering 2018)	v201912

Product Name	Update description	CMEMS Version/Date of EIS
WAVERYSv1 GLOBAL_REANALYSIS _WAV_001_032	GLOBAL 1/4° wave reanalysis V1.1: Correction of some issues with assimilation of Hs observed by satellites + Time extension over year 2019	v202007

Table 3 : Main characteristics and recent evolutions of the global biogeochemical products and reanalysis systems.

Product Name	Update description	CMEMS Version/Date of EIS
BIORYS4v4 GLOBAL_REANALYSIS _BIO_001_029	GLOBAL 1/4° biogeochemical reanalysis (non assimilative hindcast) Extend time serie to june 2018 + new variables	v201907
BIORYS4v4 GLOBAL_REANALYSIS _BIO_001_029	GLOBAL 1/4° biogeochemical reanalysis (non assimilative hindcast) Product extended to year 2019, now forced by ERA5 atmospheric fields	v202007
MICRORYSv1 GLOBAL_REANALYSIS _BIO_001_033	GLOBAL 1/4° micronekton reanalysis (non assimilative hindcast Microncton reanalysis at 1/4°	v201907
MICRORYSv1 GLOBAL_REANALYSIS _BIO_001_033	GLOBAL 1/4° micronekton reanalysis (non assimilative hindcast Extend time serie of Micronecton reanalysis at 1/4° to 2018	v201912
MICRORYSv1 GLOBAL_REANALYSIS _BIO_001_033	GLOBAL 1/4° micronekton reanalysis (non assimilative hindcast Extension of six months up to end 06/2019 of the former time series 1998-2018 with the same model calibration and forcing fields	v202007

12. GODAE OceanView related achievements and measures of success

Some activities have been conducted during the year based on Task Team collaborative work.
In the framework of the Task Team OSEval thanks to the SMOS Nino 2015 project funded by ESA, the impact of assimilating Sea Surface salinity observations from different satellites was assessed on the Met Office and the Mercator Ocean analysis and forecasts. Positive impact on the surface salinity was found in the Tropical Pacific ocean in both systems. On the other forecasted variables, different behaviours were found in the two systems. The analysis of the assimilation experiments using a common framework lead to the publication of Observing Impact Statement (M. Martin et al., 2018)

In the framework of the GOV IV Task Team, Mercator Ocean is contributing to several activities as:

● Class 4 intercomparison with share data regularly uploaded on a common data server

- MultiModel Ensemble approach including the global ¼° Mercator Ocean system
- GOV/CLIVAR/GSOP project on ocean reprocessed products and reanalysis including Mercator Ocean reanalysis

Martin, Matthew & King, Robert & While, James & Aguiar, Ana. (2018). Assimilating satellite sea surface salinity data from SMOS, Aquarius and SMAP into a global ocean forecasting system. Quarterly Journal of the Royal Meteorological Society. 145. 10.1002/qj.3461

System Information overview

System name	GLO12 and BIO4 real time forecasting system
Ocean Models	
OGCM	NEMO. PISCES biogeochemical component is coupled to the system in an offline mode and at lower resolution (1/4°)
Domain	GLOBAL
Horizontal resolution	1/12°
Vertical sampling	50 vertical levels, 1m at the surface
Atmospheric Forcing	ECMWF
Assimilation characteristics	
Assimilation Scheme	SAM2 SEEK filter including 3Dvar large scale bias correction
SST	OSTIA SST delivered by CMEMS, one map per week is assimilated
SSH	Along track Sea Level anomaly from all available satellites delivered by CMEMS. In 2019, S3b was included in the system
Other	In situ temperature and salinity profiles from CMEMS Sea ice concentration maps delivered by CMEMS Ocean Color maps delivered by CMEMS
System Set-ups	
Forecast range	10-day
Update frequency	Daily
Hindcast length	From 2006 note that only a 2-year sliding window time series is available on the CMEMS portal A global reanalysis base on the same system provides longer time series (from 1993), main differences with the real time system concern input files as reanalysis atmospheric forcing and reprocessed data set.
System website links	
General information	http://marine.copernicus.eu/services-portfolio/access-to-products/?option=com_csw&view=details&product_id=GLOBAL_ANALYSIS_FORECAST_PHY_001_024

Technical description	http://marine.copernicus.eu/documents/PUM/CMEMS-GLO-PUM-001-024.pdf http://marine.copernicus.eu/documents/QUID/CMEMS-GLO-QUID-001-024.pdf
Viewing service	http://marine.copernicus.eu/services-portfolio/access-to-products/?option=com_csw&view=details&product_id=GLOBAL_ANALYSIS_FORECAST_PHY_001_024

System name	**IBI36 real time forecasting system**
Ocean Models	
OGCM	NEMO. PISCES biogeochemical component is coupled online at the same resolution
Domain	Iberian Biscay and Irish Seas (IBI)
Horizontal resolution	1/36°
Vertical sampling	50 vertical levels, 1m at the surface
Atmospheric Forcing	ECMWF
Assimilation characteristics	
Assimilation Scheme	SAM2 SEEK filter including 3Dvar large scale bias correction
SST	OSTIA SST delivered by CMEMS, one map per week is assimilated
SSH	Along track Sea Level anomaly from all available satellites delivered by CMEMS. In 2019, S3b was included in the system
Other	In situ temperature and salinity profiles from CMEMS
System Set-ups	
Forecast range	10-day
Update frequency	Daily
Hindcast length	From 2006; note that only a 2-year sliding window time series is available on the CMEMS portal. The IBI reanalysis at lower resolution (1/12°) provides a longer time serie (from 1993), main differences with the real time system concern input files (reanalysis atmospheric forcing and reprocessed input ocean observations).
System website links	
General information	http://marine.copernicus.eu/services-portfolio/access-to-products/?option=com_csw&view=details&product_id=IBI_ANALYSIS_FORECAST_PHYS_005_001
Technical description	http://marine.copernicus.eu/documents/PUM/CMEMS-IBI-PUM-005-001.pdf

	http://marine.copernicus.eu/documents/QUID/CMEMS-IBI-QUID-005-001.pdf
Viewing service	http://marine.copernicus.eu/services-portfolio/access-to-products/?option=com_csw&view=details&product_id=IBI_ANALYSIS_FORECAST_PHYS_005_001

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