Service evolution in Copernicus Marine

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ESA World Ocean Circulation User Consultation Meeting 2022

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The EU Copernicus Marine Service Global & Regional Ocean Monitoring and Forecasting









The EU Copernicus Marine Service Ocean current products



OBSERVATIONS In-situ & Satellites







<u>In situ</u>

- Drifting buoys
- HF-radar
- Argo drift at depth
- VM-ADCP



- Surface and 15m Copernicus-GlobCurrent
- ARMOR3D (3D geost)
- OMEGA3D (3D + vertical)

+ WIND & WAVE products

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NUMERICAL MODELS & data assimilation



<u>7 MFCs</u>

- w/wo tides, w/wo wave coupling
- 15-min to hourly at the surface
- hourly to daily mean 3D
- + vertical current velocities (Nov22)

marine.copernicus.eu

Copernicus Marine service evolution principles







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A user-driven, continuously evolving service to remain state-of-the-art and a leading service for Copernicus

- The continuous improvement approach is applicable to all Copernicus Marine Service elements: production centers, marine data store, web & service
- User & policy driven: user feedbacks & policy needs are monitored and translated into service/products evolution objectives
- <u>Science driven</u>: Scientific (observations, modelling, assimilation, AI) and technological (e.g. cloud and computing capabilities) advances are fully taken into account
- <u>Guidance</u> from our international, independent experts from the Scientific and Technical Advisory Committee (STAC)
- Need to maintain **competitiveness** wrt international actors
- Innovation capacity required to attract new users/new applications (e.g. new products)
- **Delineation with downstream activities** shall be considered. The core service focuses on activities best performed at pan-European scale

Service evolution strategy: R&D priorities





https://marine.copernicus.eu/about/serv ice-evolution-strategy

Copernicus Marine service evolution strategy document → 8 R&D areas defined

- Next generation of integrated ocean forecasting systems
- High-resolution monitoring and forecasting of the blue ocean
- Marine coastal environment
- Arctic Ocean: sea-ice analysis, modelling and forecasting
- Biogeochemistry and marine biology
- Space and in situ observations and impact studies
- Ocean climate products, indicators and projections
- Machine learning, AI, big data and high-level data products

Service evolution strategy: R&D priorities



Document prepared by the Copernicus Marine Scientific and Technical Advisory Committee (STAC)

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https://marine.copernicus.eu/about/serv ice-evolution-strategy

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8 R&D areas → topics of evolution & required developments links to ocean currents

- Better representation of surface currents (0-20 m depth) and higher-frequency processes (e.g., tides) including their effects (e.g., rectification) and associated uncertainties on the circulation and on the transport of tracers.
- Improvement of **surface coastal current products** for search and rescue applications, marine debris and larval dispersion
- Adaptation of assimilation interfaces (e.g., observation operators) to new satellite sensors: wide-swath altimetry, ocean colour, SST from Sentinels, surface currents etc.
- Impact studies of new observation data types or products for ocean analyses, forecasts and reanalyses (e.g., SSS from space, sea ice thickness from Cryosat and SMOS, **surface current data sets**, BGC-Argo, HF Radars, etc.).
- More consistent processing and assembly of data from different, heterogeneous observation platforms and sensors for estimating derived quantities (e.g., sea-ice products, surface currents, MLD, PP, nutrients from temperature, salinity and O2 vertical profiles etc.).
- Al techniques for reconstructing satellite observations and recovery of total currents from SSH observations.



Service evolution activities: R&D streams





Short-term R&D





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• **Tier-1 activities (1-year cycle):** addressed within Copernicus Marine through production centres (TACs, MFCs) activities and resulting in regular updates of the catalogue

MFC: Monitoring & Forecasting Centres GLO ARC BAL NWS MFC MFC MFC MFC IBI MED BS MFC MFC MFC MFC MFC

Production centres

TAC: Thematic Assembly Centres

ICE
TACWIND
TACSL
TACINS
TACOC
TACSST
TACWAVE
TACMULTI
OBS
TAC

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Production centresMFC: Monitoring & Forecasting CentresGLO
MFCARC
MFCBAL
MFCNWS
MFCIBI
MFCMED
MFCBS
MFC

TAC: Thematic Assembly Centres



MFCs: continuous improvements, coupling effect (wave induced effect on surface currents), increase of resolution (H,V,T)

SL TAC: addition of geostrophic current in the across-track direction (L3 at 5Hz ~1km)

INS TAC: Argo drift at depth in MY

MOB TAC:

- Copernicus-Globcurrent: provision of individual components (geostrophy & wind driven) + increase of T res. to 1 hour (MY, NRT), investigation of new upstream data (ERA*, OPS*)
- ARMOR3D: increase of H res. to 1/8°, use of new IA method for step1 of the method
- OMEGA3D: uptake of R&D performed during ESA WOC project

Mid-term R&D





• Tier-2 activities (2-year cycle): addressed within Copernicus Marine both through production centres (TACs, MFCs) activities and open R&D Service Evolution calls

First R&D call in Copernicus 2 issued → 14 projects selected

Call INNOVATION SERVICE EVOLUTION – R&D PROJECTS, targeting:

- Next generation of ocean forecasting systems
- Marine coastal environment
- Ocean climate
- Artificial intelligence
- All topics of the R&D roadmap

Copernicus 1: two R&D calls for tenders (2016 and 2018) – 30 projects



Main outcomes of Copernicus 1 SE calls links to ocean currents







- Addition of new products a/o upgrade of Copernicus Marine systems:
 - Observations from **European HF-radars**
 - Upgraded **mean dynamic topography** in **coastal** areas
 - Enhanced representation of **coupling effects between** ocean-wave-seaice-atmosphere components (including Stokes-Coriolis drift, surface wave induced mixing, modified momentum exchanges...)
 - Improved **modelling of tides** with a flexible lagrangian-eulerian vertical coordinate
 - Development of **probabilistic forecasts**, model **ensembles** and better characterisation of **errors** and **uncertainties**
 - Better exploitation of **observations** with improved interpolation (satellite) based on **machine learning** methods

https://marine.copernicus.eu/about/research-development-projects



Long-term R&D

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OCEAN





• **Tier-3 activities (3-10-yr cycle):** required to prepare major evolutions. Addressed externally, with strong links with e.g. H2020/Horizon-EU, ESA. Requires high-level coordination to prepare and ensure an efficient uptake



1st Copernicus 2 service evolution call



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MERCATOR

https://marine.copernicus.eu/about/rese arch-development-projects



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Lot	Short name	Long name	PI
1	MULTICAST 🗸	Stochastic MULTI-grid ocean foreCASTing	Vassilios Versatis (IASA)
1	ODESSA 🗸	Optimal Design of Ensemble-based Simulation Systems for Applications to marine forecasting	Luc Vandenbulcke (Univ. Liège)
2	MultiRes	Generation of multi-resolution, daily and gap-free ocean colour satellite products for coastal applications	Aida Alvera-Azcarate (Univ. Liège)
2	Coastal-risks	Predicting risks of the German Bight coasts under extreme storm events	Benjamin Jacob (Hereon)
2	EstuarIO 🗸	Estuarine box model for Interfacing rivers and Ocean	Giorgia Verri (CMCC)
3	WAMBOR	evaluation of the Water Mass Balance in Ocean Reanalyses with space geodetic measurements	Julia Pfeffer (Magellium)
3	OCROC	Ocean Color Radiometry for the assessment of the particulate and dissolved Organic Carbon over both open and coastal waters	Hubert Loisel (Univ. du Littoral Côte d'Opale)
4	4DVarNet-OFDA	4DVarNet emulators for Ocean Forecasting and Data Assimilation	Ronan Fablet (IMT Atlantique)
4	COSI	Calibration Of Sea-Ice forecasts	Cyril Palerme (Met No)
4		Know-how building in Artificial Intelligence driven coastal products - Leveraging forecast Applications through Novel Implementations of remote sensing data within Copernicus Marine Service	Manuel Garcia-Leon (Nologin)
5	SODA	Sargassum Operational Detection Algorithms	Marion Sutton (CLS)
5	SLICING 🗸	Sea Level Innovations and Collaborative Intercomparisons for the Next- Generation products	Clément Ubelmann (DATLAS)
5	ADEOS 🗸	Ais-DErived Ocean Surface currents	Clément Le Goff (e-Odyn)
5	GLOPHYTS	Global Long-term Observations of Phytoplankton Functional Types from Space	Hongyan Xi (AWI)

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4DVarNet-OFDA



4DVarNet emulators for Ocean Forecasting and Data Assimilation

PIs: <u>Ronan Fablet</u> (IMT), Yannice Faugère (CLS), Lucille Gaultier (Ocean DataLab), Julien Le Sommer (IGE), Maxime Beauchamp (IMT), Hugo Georgenthum (IMT), Daniel Zhao (IMT), Clément Dorffer (IMT), Said Ouala (IMT), Benjamin Carpentier (CLS), Anaëlle Tréboutte (CLS), Fabrice Collard (Ocean DataLab)

Lead institute: IMT Atlantique

Co-contractors: CLS, Ocean DataLab

Objectives / key deliverables:

- Improve the reconstruction and forecasting of SSH and SSC
- Approach based on deep differentiable emulators based on a variational DA formulation = 4DVarNets
- Generation of global mapping of SSH (+uncertainties) from multi-source satellite data (OSSE: nadir + SWOT)
- Generation of short-term forecasting of the SSC from multi-source satellite data (real data: SSH, SST, OC) (case study=Agulhas current)
- Code (4DVarNet architectures & associated training schemes)

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Sea Level Innovations and Collaborative Intercomparisons for the Next-Generation products

PIs: <u>Clément Ubelmann</u> (OXALIS/DATLAS), Sammy Metref (DATLAS), Maxime Ballarotta (CLS), Clément Busché (CLS), Maxime Beauchamp (IMT)

Lead institute: OXALIS/DATLAS

Co-contractors: CLS, IMT Atlantique

Objectives / key deliverables:

- Provide a framework for collaborative data challenges for the next-generation sea level anomaly metrics, observation and mapping products (incl. SWOT)
- Set up protocols for validation metrics for L3 and L4 sea level products
- Test the protocols for nadir altimetry mapping (L4) from several methods (BFN-QG, MIOST, 4DVarNet) over the European basin and at Global scale
- Prepare SWOT data for L3 product distribution, incl. data challenge on noise filtering & calibration
- 4 data challenges delivered + outcomes (recommendations)











Ais-DErived Ocean Surface currents

PIs: <u>Clément Le Goff</u> (E-ODYN), Brahim Boussidi (eOdyn), Anne Piron (eOdyn), Franck Dumas (SHOM), Lucie Bordois (SHOM), Stéphane Raynaud (SHOM), Pierre Tandeo (IMT)

Lead institute: E-ODYN

Co-contractors: IMT Atlantique, SHOM

Objectives / key deliverables:

- Compute ocean surface currents through the use of AIS (Automatic Identification System) messages
- Improve the interpolation scheme using a Kalman filtering instead of optimal interpolation + compute associated uncertainties
- Develop and apply a number of metrics and tools to analyse/validate the AISderived currents in 6 different regions of the world having different characteristics (Med Sea coastal, Strait of Gibraltar, Congo river plume, Agulhas current, Gulf of Mexico, high latitude...)
- New surface current datasets to be included in INSITU TAC





Le Goff et al., 2021





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Know-how building in Artificial Intelligence driven coastal products - Leveraging forecast Applications through Novel Implementations of remote sensing data within Copernicus Marine Service

PIs: <u>Manuel Garcia-Leon</u> (Nologin), Roland Aznar (Nologin), José Maria Garcia-Valdecasas (Nologin), Lotfi Aouf (Météo-France), France), Alice Dalphinet (Météo-France), José Maria Terrés Nicoli (Oritia&Boreas), Javier García-Valdecasas (Oritia&Boreas), José Manuel López Collantes (Oritia&Boreas)

NOLOGIN

Lead institute: Nologin

Co-contractors: Météo-France, Oritia & Boreas

Objectives / key deliverables:

- Improve regional wave forecasts by improving the inputs required by the model (=wind & surface current forcing)
- Use of AI NN (ANNs), trained with data (SAR & HFR), to correct biases and errors in coastal winds and surface currents forecasts
- Blend these coastal forecasts with IBI-region forecasts
- Development of a pre-operational chain for IBI-WAV

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SERVICE

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Copernicus Marine a continuously evolving product offereesa

- Essential role of the different R&D tiers of activities to stay state-of-the-art and responsive to users
- Essential role of the different actors who contribute to these different R&D tiers
- Guidance by the Copernicus Marine international Scientific and Technical Advisory Committee
- 2022-2024 evolutions: new products, new variables, upgraded quality, temporal extension of products,...
- 14 Tier-2 R&D projects launched
- 2nd call of R&D projects planned end 2023



