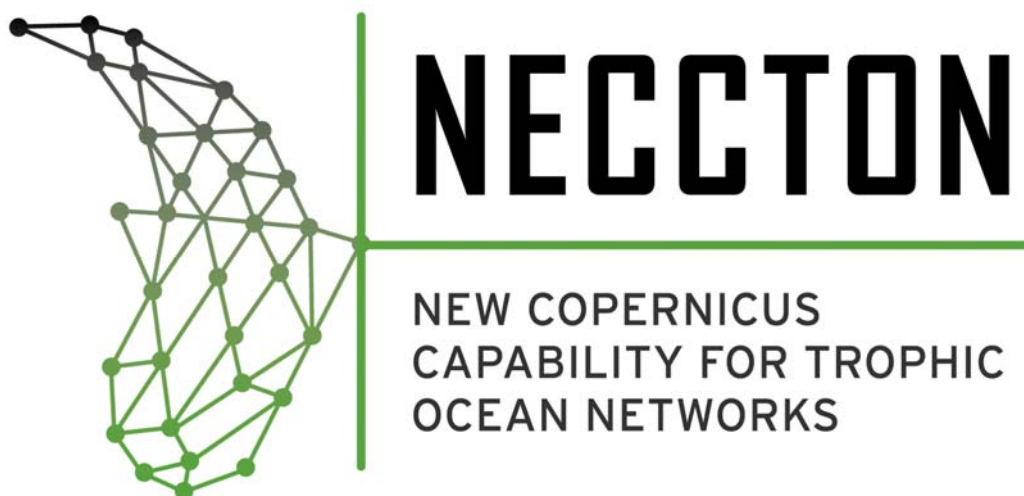


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Dissemination	Public	Nature	Report
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Deliverable D6.1

Technical specification of the benthic products

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Dissemination	Public	Nature	Report
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Document History:

Release	Date	Reason for Change	Status	Distribution
1.0	31/10/2023	Final version submitted to EC	Submitted	Public
0.1	16/10/2023	Draft submitted for review	In progress	Internal
0.0	31/08/2023	Initial document (table of content)	In progress	Internal

Preface

This document is the deliverable D6.1 of the Task 6.1 of NECCTON. Its objective is to define the product and services for the benthic component of ocean ecosystem, co-developed by work-package 6 and the project stakeholders.

To cite this document: Gregoire et al (2023). D6.1 “Technical specification of the benthic products”. Report of the Horizon Europe NECCTON project (grant 101081273). DOI: 10.5281/zenodo.10057896

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Glossary

Product In NECCTON, a "product" is the output of a model, or of a coupled model, developed in the project. The product is assessed as a potential new variable for the Copernicus Marine Service. Each product can be delivered as a number of co-products, e.g., by different models in different regions. Each co-product is composed of a set of sub-variables and delivered as a model-output dataset.

Sub-variable In NECCTON, a sub-variable is a single component of the product that is simulated by the model and used to estimate the desired product. For example, suspended particular matter is a product that may be estimated as the sum of sub-variables representing matter with different sizes.

Dataset The NECCTON products will be delivered in the form of "datasets". These are aggregations of model outputs or observations, having the same geospatial structure or feature type (e.g., profiles, point-series, trajectories, points, grid-series, grids). A dataset contains data relative to one or more products developed by NECCTON. It is composed of one or several data files. The aggregation is done so that the content of the dataset is FAIR for the user (findable, accessible, interoperable, and reusable) and expandable when the product is updated (time axis).

Datacube The NECCTON "datacube exploratory viewer" is an interactive application for exploring and visualizing the datasets, adapted to the visualization of the NECCTON products simulated by the integrated ecosystem model. This datacube is based on innovative cloud-based technologies and will use a serverless architecture that allows it to connect directly to files and not to a server. This viewer will guarantee high-availability, visual analysis, and flexible data dissemination to the users

Service In NECCTON, a service is a tool (e.g., software) that transforms the data of a product into information needed by a stakeholder for a specific application. Most notably, the NECCTON datacube is a service that will map features of the data selected by the user.

Derived product In NECCTON, a derived product is the output of a service, which is calculated from an original product and other relevant information, in response to user needs. For example, the space-time occurrence of suspended particulate matter above chosen thresholds is a derived product, that could be an output of the NECCTON datacube.

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Publishable Summary

The NECCTON D6.1 report provides a clear definition of the benthic products delivered by NECCTON WP6. We intend this report to serve as a reference for internal and external users of the products. The definitions respond to the requirements of users that emerged from the NECCTON workshop “Co-design of future products”, which was held on-line in June 2023 (>100 stakeholders attending) and the related online survey “Product co-design”, which was live from July to September 2023 (>200 respondents). In this document, the definition of the products includes a brief review of previous and ongoing efforts in defining and delivering the product in an operational framework, as well as a description of the expected exploitation by users and associated impact.

This document also describes the datasets produced by NECCTON to deliver the products to internal and external users. These descriptions include features of the product, such as their spatial coverage and resolution, and their temporal extension and resolution. It also includes a description of the metadata provided in the files containing the datasets.

WP6 will deliver an ambitious 29 new model products distributed over 4 Copernicus Marine regions: the North, Baltic, Mediterranean, and Black Seas. The new products include Suspended Particulate Matter, bottom oxygen, bottom pH, bottom light, carbon flux to the sediment, sedimentary organic carbon content, benthic flora and faunal maps, sedimentary carbon sequestration, and denitrification rates. We expect the new products to benefit work on benthic habitat mapping, food web and higher-trophic-level modelling, carbon and nitrogen budgeting over the continental shelf, benthic functions mapping, and environmental health assessment.

The engagement of stakeholders to tailor the WP6 NECCTON products to user needs will continue through the duration of the project based on the co-design of thirteen case studies, dedicated workshops, and the engagement of other European projects, initiatives, and networks (including the Copernicus Marine Service user groups).

1. Introduction

1.1 Scope of document

The objective of this document is to provide a clear definition of the benthic products delivered by NECCTON WP6 and to serve as a reference for internal and external users of the products. The definition is based on the requirements of users that emerged from the NECCTON workshop “Co-design of future products”, which was held on-line in June 2023 (more than 100 stakeholders attending) and the associated survey “Product co-design” held from July to September 2023 (> 200 respondents). In this document, the definition of the products includes a brief review of previous and ongoing efforts in defining and delivering the product in an operational framework, as well as a description of the expected exploitation by users and associated impact.

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This document also describes the datasets produced by NECCTON to deliver the products to internal and external users. These descriptions include features of the product, such as: their spatial coverage and resolution, and their temporal extent and resolution. It also includes a description of the metadata provided in the files containing the datasets.

As noted earlier, all products and datasets delivered by NECCTON follow the FAIR principle: they are findable, accessible, interoperable and reusable (see the “Data Management Plan” D1.1). In particular, NECCTON datacube is the main service for the dissemination and use of the products and datasets described here. Therefore, this document describes the compatibility of the datasets with the datacube.

We point out that the models producing the datasets in WP6, the datacube developed in WP2, and potential derived products collectively represent the specific focus of other future deliverables of NECCTON. Therefore, we consider their description beyond the scope of the present document.

We note that the terminology in the glossary is consistent with the one in the Specification Sheets of the Essential Ocean Variables, defined by the Expert Panels of the Global Ocean Observing System (GOOS). GOOS is an Intergovernmental Oceanographic Commission (IOC)-led programme (<https://www.goosocean.org>)

<https://www.goosocean.org/> Whenever available, we used the Climate and Forecast (CF) standard metadata conventions or criteria to define the metadata of the NECCTON products and sub-variables (e.g., long-names, units; <https://cfconventions.org/>). When these were not available, we made here new propositions, following the CF criteria, that might be refined through the engagement of experts and users during the future delivery of the project, by using this document as a discussion platform.

1.2 Intended audience and reference to user needs

This document is designed as a guide for the NECCTON partners as well as future users of the new products delivered by WP6 of NECCTON. WP6 is working closely with WP1 (Management), WP2 (Stakeholders) and WP9 (Case studies) to ensure that these products correspond to user needs.

The user needs for the WP6 products emerged from the session 6 of the NECCTON workshop “Co-design of future products” held on-line in June 2023 (about 60 stakeholders attending the specific WP6 sessions) and the W6 dedicated section of the survey “Product co-design”, held from July to September 2023. An analysis of the attendants and results of the above workshop session and survey section indicated that most of the respondents identified as scientists or researchers (79 % for the online survey; 86 % for the workshop). In the online survey, 64 % of the respondents worked in academia, with the remainder working for other organisations, including non-governmental organisations and consultancies. In summary, stakeholders are interested in the provision of benthic products: for scientific research and analysis and to support the policy making process, in particular, related to conservation. Suspended Particulate Matter (SPM), benthic oxygen, species maps (biomass first then presence/absence and traits), the carbon flux to the seabed and carbon content at the seabed are the products that receive the highest interest. Historical data and climate projections (over a time scale of 20-40 years) at monthly and a few km resolution are ranked highest as user needs. For

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the SPM, the shorter time scales, with daily to weekly forecasts and past reconstruction were ranked highest.

The engagement of the stakeholders to tailor the WP6 NECCTON products to the user needs will continue throughout the duration of the project by co-designing thirteen case studies, dedicated workshops and engaging with other European projects (e.g. OceanICU, BRIDGE-BS), initiatives and networks (including the Copernicus Marine Service user groups).

1.3 Structure of the document

The document is structured as follows. Section 2 provides a synthetic list of the products that will be delivered by WP6. Section 3 provides a thorough description of each product, including: i) a general definition; ii) the user requirements, iii) the current state of the art, iv) planned evolution of the product delivery, v) the observations expected to be used to assess the model datasets, vi) the expected exploitation and impact of the product, and vii) key metadata of the product. Section 4 describes the datasets planned in NECCTON to deliver the products to users. A summary of possible challenges and expected impacts is given in Section 5.

2. Products summary

The NECCTON products (see definition in the glossary) that are delivered by WP 6 are listed in Table 2.1, along with selected, high-level information. This provides the reader and product users with an overview of the data delivered by NECCTON, as well as with identifiers to retrieve the product and dataset specifications in Sections 3 and 4. The datasets are delivered by hindcasts (H), i.e. model simulation of the past, which are named with unique numeric identifiers (H1, H2, ...).

Table 2.1 List of the co-products delivered by WP 6. First column: name of the product; second column: product ID; third column: ID dataset used to support the development of the product; fourth column: Copernicus Marine Service region; fifth column: model to be used for creating the product; and sixth column: NECCTON partner responsible for delivering the product.

Name product	ID co.product	ID datasets	Region	Partners
Suspended particulate matter SPM	3.1	H2	North-Western shelf	UKMO
Suspended particulate matter SPM	3.2	H3	Black Sea	UoL/Hereon
Bottom Oxygen	7.1	H6	Mediterranean	OGS
Bottom Oxygen	7.2	H3	Black Sea	UoL
Bottom Oxygen	7.3	H2	North-western shelf	UKMO

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Bottom Oxygen	7.4	H5	Baltic Sea	BSH
Bottom pH	8.1	H6	Mediterranean	OGS
Bottom pH	8.2	H3	Black Sea	UoL
Bottom pH	8.3	H2	North-western shelf	UKMO
Bottom pH	8.4	H5	Baltic Sea	BSH
Bottom Light	9.1	H6	Mediterranean	OGS
Bottom Light	9.2	H41	Black Sea	UoL
Bottom Light	9.3	H2	North-western shelf	UKMO
Bottom Light	9.4	H5	Baltic Sea	BSH
Carbon flux to the bottom	10.1	H6	Mediterranean	OGS
Carbon flux to the bottom	10.2	H3	Black Sea	UoL
Carbon flux to the bottom	10.3	H2	North-western shelf	UKMO
Carbon flux to the bottom	10.4	H5	Baltic Sea	BSH
Carbon in bottom	11.1	H3	Black Sea	UoL
Carbon in bottom	11.2	H2	North-western shelf	UKMO
Carbon in bottom	11.3	H5	Baltic Sea	BSH
Macrozoobenthos	12.1	H22	Mediterranean Sea	OGS
Macrozoobenthos	12.2	H2	North-western shelf	UKMO/PML
Macrozoobenthos	12.3	H40	Black Sea	NIOZ
Benthic Flora	13.1	H22	Mediterranean Sea	OGS
Benthic Flora	13.2	H40	Black Sea	NIOZ
Sedimentary rates	26.1	H40	Black Sea	UoL
Sedimentary rates	26.2	H40	Black Sea	UoL

3. Product definition

The next sections provide thorough definitions of each product listed in table 2.1.

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3.1 Product Suspended Particulate Matter (SPM)

3.1.0 Introduction

Suspended particulate matter (SPM) refers to a mixture of clay to sand-sized particles that can be detected in suspension, and that consists of minerals from physical-chemical and biogenic origin, living and non-living organic matters (Fettweis et al., 2019). SPM integrates all suspended particles including mineral (sand, silt, clay) and organic components, which are further split into the living (e.g. phytoplankton, zooplankton) and non-living components (organic detritus) (Wang et al., 2022). Researchers use SPM as an indicator of sediment transport, water clarity, and quality; SPM has important implications for pelagic and benthic productivity and for the transfer of contaminants.

3.1.1 User feedback and requirements

A substantial proportion of stakeholders (~50%) have indicated interest in an SPM product with a clear preference for scales of a few kilometres and less, at daily resolution (or even less) up to monthly time scales, in applications that concern past reconstructions or short-term (daily) forecasts. The main interest in a SPM product is driven by applications that concern the implications of SPM for visibility, shading or as a vector for nutrient transport.

3.1.2 State-of-the-art on product delivery and gaps

The current Copernicus Marine Service delivers only subproducts of the SPM, mainly phytoplankton and zooplankton concentrations. The Service does not deliver the mineral components.

3.1.3 How NECCTON will innovate the product and fill the gap

NECCTON will add additional components of SPM (e.g. the mineral fraction) and improve modelling of SPM components by including the effect of waves on benthic SPM resuspension/deposition processes, and by adding an aggregation module.

3.1.4 Observational data available for product calibration/assimilation/validation

The many components of SPM complicate straightforward validation. We will use satellite products of optically active SPM as well as information on optical properties such as the backscattering coefficient delivered by BGC-ARGO.

3.1.5 Expected users' uptake

Users mentioned interest in SPM for estimating water clarity and hence light available for benthic ecosystems, as well as SPM as a source of nutrients for benthic species.

3.1.6 List of co-products, sub-variables and metadata in the data-files for this product.

Please note that the inorganic SPM product (SPM_min) is a join product between WP5 and WP6.

Co-product ID	Co-product
3 (3.1, 3.2)	Suspended Particulate Matter
Sub-variable name [unit]	<i>Inorganic Suspended Particulate Matter</i> [g m ⁻³]
Description	Mass concentration of suspended inorganic matter in sea water

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Long name	Mass concentration of suspended inorganic matter in sea water
Short name	SPM_min
Standard_name	mass_concentration_of_suspended_inorganic_particulate_matter_in_sea_water
Sub-variable name [unit]	Organic Suspended Particulate Matter [mmol C m ⁻³]
Description	Mass concentration of suspended organic matter in sea water
Long name	Mass concentration of suspended organic matter in sea water
Short name	SPM_org
Standard_name	mol_concentration_of_suspended_organic_particulate_matter_in_sea_water

3.2 Product Bottom Oxygen

3.2.0 Introduction

Bottom Oxygen concentration is an indicator of ecosystem health and particularly the presence of coastal hypoxia that often occurs at the bottom.

3.2.1 User feedback and requirements

Deoxygenation is one of the three major climate stressors. Environmental management (e.g. MFSD) often require an estimate of the extent of hypoxia and its duration in relation to ecosystem health. Many users (69%) express interest in this product at a few kms (or higher) resolution at monthly and even daily resolution.

3.2.2 State-of-the-art on product delivery and gaps

Copernicus Marine Service already delivers oxygen concentration but important processes such as benthic organic matter degradation, erosion/deposition of organic material, macrozoobenthic respiration are currently not well represented.

3.2.3 How NECCTON will innovate the product and fill the gap

NECCTON expects to improve bottom oxygen prediction via a better representation of the benthos and benthic-pelagic coupling. Oxygen is already a product of all the marine forecasting centers in Copernicus Marine Service. However, the level of bottom water oxygen concentration depends on benthic activity. Yet so far, marine forecasting centers poorly describe or even ignore the benthos. NECCTON will improve the quality of bottom oxygen products through better modelling of benthic systems.

3.2.4 Observational data available for product calibration/assimilation/validation

This objective will use data from Copernicus Marine Service Thematic Assembly Center (TAC).

3.2.5 Expected user uptake

Maps of bottom oxygen and its changes in time can support environmental management. For instance, regions systematically affected by hypoxia require protection from other stressors, and maps can help to identify underlying causes to inform mitigation strategies.

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3.2.6 List of co-products, sub-variables and metadata in the data-files for this product

Co-product ID	Co-product
7 (7.1, 7.2, 7.3, 7.4)	Bottom Oxygen
Sub-variable name [unit]	<i>Dissolved Oxygen at the bottom</i> [mol m ⁻³]
Description	-
Long name	Dissolved Oxygen at the bottom
Short name	O2b
Standard_name	Mole_concentration_of_dissolved_molecular_oxygen_in_sea water*
* available CF metadata (https://cfconventions.org/)	

3.3 Product Bottom pH

3.3.0 Introduction

Potential Hydrogen, better known as pH, is a measure of acidity/ basicity of a solution expressed on a logarithmic scale; a pH of 7 denotes a neutral solution whereas lower and higher values characterise more acidic and alkaline waters, respectively, compared to the neutral state. Studies generally report pH on a concentration scale representing a measure of proton activity. As a measure of acidification, pH represents an important indicator of ecosystem health.

3.3.1 User feedback and requirements

About a third (31%) of users expressed interest in a bottom pH product at a few kms (or higher) resolution and monthly or even daily resolution.

3.3.2 State-of-the-art on product delivery and gaps

Copernicus Marine Service delivers pH but, similarly to oxygen, it provides imperfect representation of important processes such as benthic organic matter degradation, erosion/deposition of organic material, and macrozoobenthic respiration, any of which may lead to biases in modelled pH, especially in near-bottom layers.

3.3.3 How NECCTON will innovate the product and fill the gap

NECCTON expects to improve bottom pH prediction through better representation of the benthos and benthic-pelagic coupling. All the marine forecasting centers in the Copernicus Marine Service already provide pH, however, pH of bottom waters depends on benthic activity. Yet so far, marine forecasting centers poorly describe or even ignore the benthos. NECCTON will improve the quality of bottom pH products thanks to a better modelling of the benthic system.

3.3.4 Observational data available for product calibration/assimilation/validation

Product calibration/assimilation/validation will use data from Copernicus Marine Service TAC.

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3.3.5 Expected users' uptake

Maps highlighting areas prone to pH reduction can support environmental management. For instance, regions systematically affected by acidification need protection from other stressors, and identification of underlying causes can inform mitigation strategies.

3.3.6 List of co-products, sub-variables and metadata in the data-files for this product

Co-product ID	Co-product
8 (8.1, 8.2, 8.3, 8.4)	Bottom pH
Sub-variable name [unit]	pH at the bottom
Description	-
Long name	pH at the bottom
Short name	pHb
Standard_name	sea_water_ph_reported_on_total_scale*
* available CF metadata (https://cfconventions.org/)	

3.4 Product Bottom Light

3.4.0 Introduction

Bottom light availability is an important environmental information in determining regions where marine flora – seaweeds, seagrasses and microphytobenthos – can develop. We will deliver the bottom light product as Photosynthetic Active Radiation (PAR), which includes radiation wavelengths between 400-700 nm.

3.4.1 User feedback and requirements

Almost half (46%) of the respondents identified light availability at the seabed as a variable they use, requiring products at a few kms (or higher) resolution at monthly or even daily resolution.

3.4.2 State-of-the-art on product delivery and gaps

Copernicus Marine Service already delivers bottom light but ignores the effect of mineral SPM in coastal areas.

3.4.3 How NECCTON will innovate the product and fill the gap

NECCTON expects to improve the prediction of bottom light through better representation of SPM and benthic-pelagic coupling. Most of the marine forecasting centers in the Copernicus Marine Service already provide light, however, the level of light on the bottom depends on accurate representation of optically active constituents. Yet so far, products consider optically active components of chlorophylls and organic particles but do not consider inorganic components. Furthermore, this product sometimes omits or oversimplifies resuspension/deposition processes. NECCTON will improve the bottom light product using improved quality of optically active components. By including a refined representation of the SPM and, in some cases on radiative transfer, we expect to improve the quality of the light product.

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3.4.4 Observational data available for product calibration/assimilation/validation

BGC-ARGO provides irradiance at specific wavelengths (i.e. 380, 412, 490) of satellite spectral reflectance.

3.4.5 Expected users' uptake

Water clarity and light field are indicators of water quality and influence benthic photosynthetic communities. Users can specifically use this product to assess coastal darkening or as a dominant forcing to map benthic flora.

3.4.6 List of co-products, sub-variables and metadata in the data-files for this product

Co-product ID	Co-product
9 (9.1, 9.2, 9.3, 9.4)	Bottom Light
Sub-variable name [unit]	Bottom Photosynthetically Active Radiation [W m ⁻²]
Description	-
Long name	Photosynthetically Active Radiation at the bottom
Short name	PARb
Standard_name	Downwelling_photosynthetic_radiative_flux_at_bottom_sea_water

3.5 Product carbon flux to the bottom

3.5.0 Introduction

The flux of organic carbon to the bottom critically drives benthic ecosystems through the benthic food chain, diagenesis, and quantity of carbon sequestration through burial. The difficulty of in-situ determination greatly limits information on carbon flow to the bottom at the ecosystem scale. Models can provide important information on carbon flux to the bottom at ecosystem scale and on its spatial and temporal variation.

3.5.1 User feedback and requirements

More than half (62%) of users expressed strong interest in carbon flux to the sediment at resolution of a few kms (or higher) and at monthly or even daily resolution.

3.5.2 State-of-the-art on product delivery and gaps

Copernicus Marine Service does not currently provide a product on flux of carbon to the bottom.

3.5.3 How NECCON will innovate the product and fill the gap

NECCON will deliver, for the first time, flux of carbon to the bottom for the North, Baltic, Black and Mediterranean Seas.

3.5.4 Observational data available for product calibration/assimilation/validation

Individual point observations of sedimentation data from past projects largely comprise the very limited available data.

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3.5.5 Expected users' uptake

We expect the carbon flux to the seabed product to support benthic habitat mapping and understanding of the biogeochemical budgets of continental shelves through the use of a better forcing of benthic-pelagic coupling. It will also help in understanding the coupling between pelagic and benthic systems and identifying regions of intense primary production, export to the seabed, and benthic activity.

3.5.6 List of co-products, sub-variables and metadata in the data-files for this product.

Co-product ID	Co-product
10 (10.1, 10.2, 10.3, 10.4)	Organic Carbon flux to the bottom
Sub-variable name [unit]	Organic Carbon flux to the bottom [mgC m ⁻² s ⁻¹]
Description	-
Long name	Organic Carbon flux to the bottom
Short name	Cfluxb
Standard_name	Bottom_sinking_mass_flux_of_organic_carbon_expressed_as_carbon_per_unit_surface_in_sea_water

3.6 Product carbon sediment content

3.6.0 Introduction

This product will provide maps of the vertically integrated carbon content in sediment for the North, Baltic, Black and Mediterranean Seas. Sedimentary carbon content provides information on the amount of food available to support the benthic food web and diagenetic processes. Its spatial distribution offers information on the functioning of benthic organisms (suspension versus deposit feeding).

3.6.1 User feedback and requirements

Roughly half (46%) of the users expressed interest in this product at resolution of a few kms or higher, and at monthly or even daily resolution.

3.6.2 State-of-the-art on product delivery and gaps.

The sedimentary carbon content is not currently a product of Copernicus Marine Service.

3.6.3 How NECCON will innovate the product and fill the gap

NECCON will deliver, for the first time, sedimentary carbon content for the North, Baltic, Black, and Mediterranean Seas.

3.6.4 Observational data available for product calibration/assimilation/validation

Sedimentary data from point observations from past projects largely comprise the very limited available data.

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3.6.5 Expected users' uptake

This product can support applications such as food web modelling, benthic habitat mapping and High-trophic-level modelling.

3.2.6 List of co-products, sub-variables, and metadata in the data-files for this product

Co-product ID	Co-product
11 (11.1, 11.2, 11.3, 11.4)	Carbon Sediment Content
Sub-variable name [unit]	<i>Sedimentary Organic Carbon content</i> [mmol C m ⁻²]
Description	-
Long name	Sedimentary Organic Carbon content
Short name	Csed
Standard_name	mole_concentration_of_organic_carbon_expressed_as_carbon_per_unit_surface_in_bottom_sediment

3.7 Macrozoobenthos

3.7.0 Introduction

The macrozoobenthos, usually defined as benthic macrofauna larger than 1 mm in size, is an essential element in benthic-pelagic coupling, because it mediates particulate and solute fluxes between the water column and sediments. It degrades organic matter that sinks to the bottom, changes biogeochemical properties of sediments via bioturbation and bioirrigation, affecting, for instance, rates of microbial oxidation and denitrification. It also serves as a food source for higher trophic levels, thus helping to sustain fish and fisheries. Macrozoobenthic communities, in turn, respond to organic matter supplied from the water column, hydrodynamic regime, and temperature. Major feeding groups (suspension and deposit feeders) differ in diet composition and vertical habitat distribution, which defines their functioning. In turn, their environment and changes in its characteristics affect these groups differently.

3.7.1 User feedback and requirements

Many users (85%) expressed interest in species maps expressed as biomass (92%), presence/absence (77%) and functions (54%) at a resolution of a few kms. As an essential component of these habitats, the spatiotemporal distribution of various functional types of macrozoobenthos can be an important indicator of ecosystem functioning and health. Users require outputs at several km-scale and at variable temporal resolution; we will therefore deliver this product at resolutions from years to months to days, depending on individual model specifications.

3.7.2 State-of-the-art on product delivery and gaps

Copernicus Marine Service does not currently provide macrozoobenthos. Most biogeochemical models do not focus on benthic environments, and thus simplify their descriptions of benthic processes, treating them largely as a pathway to return nutrients to the water column. With a few

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exceptions, these models omit explicit descriptions of macrozoobenthos, but may include parameterisations related to some aspects of their activity.

3.7.3 How NECCTON will innovate the product and fill the gap

NECCTON will, for the first time, deliver modelled macrozoobenthos datasets in the North, Black and Mediterranean Seas.

3.7.4 Observational data available for product calibration/assimilation/validation

Limited available observational data on macrozoobenthos has limited spatiotemporal resolution, and differs in sampling methods and measurement units. To calibrate and validate the model outputs, we will use available large-scale datasets, such as species maps from EMODnet Biology, GBIF, OBIS, and BenBioDen database (Stratmann et al, 2021), as well as point measurements from observational stations and cruises collected within various previous projects, and data collected by other national and international research organisms.

3.7.5 Expected users' uptake

We expect some users will want estimates of food availability for high trophic levels in order to inform assessment of ecosystem status, resilience, and susceptibility to change. Other users may want to assess ecosystem services, looking at the impact of macrozoobenthos on carbon fluxes, denitrification, oxygen demand, bioturbation potential etc. Finally, some users may wish to assess impacts of human activity, such as trawling and offshore structures on benthic habitats.

3.7.6 List of co-products, sub-variables and metadata in the data-files for this product

Co-product ID	Co-product
12.1,12.2, 12.3	Macrozoobenthos
Sub-variable name [unit]	Macrozoobenthos [mmolC m ⁻²]
Description	
Long name	Macrozoobenthos
Short name	Macrozoo
Standard_name	mole_concentration_of_macrozoobenthos_expressed_as_carbon_per_unit_surface_of_bottom_sediment
Sub-variable name [unit]	Deposit feeders [mmolC m ⁻²]
Description	
Long name	Macrozoobenthos, deposit feeders
Short name	Macrozoo_df
Standard_name	mol_concentration_of_deposit_feeder_macrozoobenthos_expressed_as_carbon_per_unit_surface_of_bottom_sediment
Sub-variable name [unit]	Suspension feeders [mmolC m ⁻²]

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Description	
Long name	Macrozoobenthos, suspension feeders
Short name	MacroZOO_sf
Standard_name	mole_concentration_of_macrozoobenthos_suspension_feeders_expressed_as_carbon_per_unit_surface_in_bottom_sediment
Sub-variable name [unit]	Mussels [Individulas m ⁻²]
Description	
Long name	Macrozoobenthos, mussels
Short name	MacroZOO_Mussels
Standard_name	density_of_macrozoobenthos_mussels_expressed_as_number_of_individuals_per_surface_area_in_bottom_sea_water

3.8 Benthic Flora

3.8.0 Introduction

Benthic flora are essential elements in benthic-pelagic coupling and in carbon sequestration (blue carbon). Besides uptake of inorganic carbon and production of oxygen, the most important species of flora are habitat builders that often help stabilise sediment (e.g., seagrasses) and provide shelter, spawning, and nursery ground for multiple species, including some of commercial interest. Moreover, benthic flora typically supports high associated biodiversity.

3.8.1 User feedback and requirements

Most (85%) of the users expressed interest in species maps based on biomass (92%), presence/absence (77%) and functions (54%) at a resolution of a few kms. Benthic flora, in particular, is an essential component of these habitats as habitat building species, influencing the distribution of other associated species. Users require outputs at several km-scale and temporal resolution of years to months, depending on model specifications.

3.8.2 State-of-the-art on product delivery and gaps

Copernicus Marine Service does not currently offer a benthic flora product.

3.8.3 How NECCTON will innovate the product and fill the gap.

NECCTON will deliver, for the first time, benthic flora biomass and mapping in the Black and Mediterranean Seas.

3.8.4 Observational data available for product calibration/assimilation/validation

Species maps from EMODnet Biology, observations available in GBIF, OBIS, and collected by other national or international research organisations comprise the few available data.

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3.8.5 Expected users' uptake

We expect some users will use this product to generate estimates of ecosystem status, resilience, and susceptibility to change. Others may assess ecosystem services, looking at impact of benthic flora on carbon fluxes, and how they provide shelter, spawning, and nursery grounds for multiple species. The benthic flora product can also help in addressing impacts of human activity, such as trawling, and modifications in coastal morphology and hydrodynamics on benthic habitats.

3.8.6 List of co-products, sub-variables and metadata in the data-files for this product

Co-product ID	Co-product
13.1,13.2	Benthic Flora
Sub-variable name [unit]	<i>Benthic Flora</i> [l mmolC m ⁻²]
Description	
Long name	Benthic Flora
Short name	Benthic_flora
Standard_name	mole_concentration_of_seagrasses_expressed_as_carbon_per_unit_surface_of_bottom_sediment
Sub-variable name [unit]	<i>Phyllophora</i> [l mmolC m ⁻²]
Description	
Long name	Benthic flora, Phyllophora
Short name	Benthic_Flora_Phyllophora
Standard_name	mole_concentration_of_benthic_macroflora_phylophora_expressed_as_carbon_in_bottom_sea_water

3.9 Sedimentary rates

3.9.0 Introduction

This product will provide maps of carbon sequestration (I.e. carbon burial) and denitrification rates (NO₃ removal) in Black Sea sediment.

3.9.1 User feedback and requirements

We added this product to the original NECCTON products (DoW) based on the stakeholder workshop held on June 28-29th. The survey did not include this product and hence we cannot derive statistics. However, during the discussion, many participants mentioned a need for information on carbon sequestration and denitrification. We therefore added an experimental product on carbon sequestration and denitrification for the Black Sea.

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3.9.2 State-of-the-art on product delivery and gaps

Copernicus Marine Service does not currently offer neither a sedimentary carbon sequestration nor sedimentary denitrification product.

3.9.3 How NECCTON will innovate the product and fill the gap

NECCTON will deliver, for the first time, maps of carbon sequestration and sedimentary denitrification in the Black Sea.

3.9.4 Observational data available for product calibration/assimilation/validation

Scattered sedimentary data from past projects comprise the very few available data.

3.9.5 Expected users' uptake

This product can be used for carbon and nitrogen budgeting over the continental shelf (here we consider the Black Sea product as experimental).

3.9.6 List of co-products, sub-variables and metadata in the data-files for this product

Co-product ID	Co-product
26.1, 26.2	Sedimentary rates
Sub-variable name [unit]	Carbon sequestration [mmolC m ⁻² y ⁻¹]
Description	
Long name	Sedimentary carbon sequestration
Short name	Cseq_sed
Standard_name	carbon_sequestration_expressed_as_mol_of_carbon_per_unit_surface_per_year_in_bottom_sea_water
Sub-variable name [unit]	Denitrification [mmolN m ⁻² y ⁻¹]
Description	
Long name	Sedimentary denitrification
Short name	Denit_sed
Standard_name	denitrification_expressed_as_mol_of_nitrogen_per_unit_surface_per_year_in_bottom_sea_water

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4. Datasets description

We will deliver the products described in Section 3 in the form of “datasets” (defined in the glossary). All the XXX datasets containing products developed by WP6 are described in the following sub-sections.

4.1 H2 – North Western Shelf

ID dataset	H2
Products names (product IDs)	Oxygen near bottom (7.3), pH near bottom (8.3), light near bottom (9.3), carbon flux to bottom (10.3), carbon in sediment (11.2), macrozoobenthos (12.2)
Name sub-variables	oxygen near bottom, pH near bottom, light near bottom, carbon flux to bottom, carbon in sediment, deposit feeders, suspension feeders
Geographical coverage	North Western Shelf
Horizontal resolution	7 km
Vertical resolution	2D maps
Time period	1991-2020
Temporal resolution	Daily
Data-file(s):	neccton-ukmo-h002_mod_nws_ben_hind_7km_P1D-m-mf_XXX
Expected total, max size of datafile(s) [Gb]:	100 GB
Format	gridded, NetCDF
Partner producer and contact	UKMO, Susan Kay, suka@metoffice.gov.uk ; PML, Gennadi Lessin, gle@pml.ac.uk
Datasets used for calibration/validation/assimilation	ICES database, Copernicus Marine in situ TAC, BenBioDen database, cruise and monitoring station datasets
Method	Coupled NEMO-ERSEM forced by ERA5 meteorology as used in Copernicus Marine reanalysis.

4.2 H3 Black Sea

ID dataset	H3
Products names (product IDs)	Bottom Oxygen (7.2), Bottom pH (8.2), carbon flux to the bottom (10.2), carbon in sediment (11.2).
Name sub-variables	same as above
Geographical coverage	Black Sea
Horizontal resolution	2.5 km
Vertical resolution	59 vertical levels
Time period	Hindcast: 1950-2023, projection: 2023-2100
Temporal resolution	daily/weekly
Data-file(s):	neccton-uol_h3_mod_blk_ben_hind_2.5km_P1D-m-mf-000, neccton-uol_h3_mod_blk_ben_proj_2.5km_P1M-m-mf-000
Expected total, max size of datafile(s) [Gb]:	100 Gb

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Format	gridded, NetCDF
Partner producer and contact	Luc Vandenbulcke, luc.vandenbulcke@uliege.be
Datasets used for calibration/validation/assimilation	Copernicus Marine in situ TAC
Method	Coupled NEMO-BAMHBI forced by MAR atmospheric conditions, climatological river inputs

4.2 H5 Baltic Sea

ID dataset	H5
Products names (product IDs)	Bottom Oxygen (7.4); Bottom pH (8.4); Bottom light (9.4); Carbon flux to the bottom (10.4); Carbon in bottom (11.3)
Name sub-variables	Dissolved oxygen at the bottom; pH at the bottom; Bottom photosynthetically active radiation; Organic carbon flux to the bottom; Sedimentary organic carbon content
Geographical coverage	Baltic Sea - Lat 53.01°N to 65.89°N; Lon 9.04°E to 30.21°E
Horizontal resolution	Lat: 0.017 degrees; Lon: 0.028 degrees (~1 nm)
Vertical resolution	56
Time period	2018-2020
Temporal resolution	Daily
Data-file(s):	neccton_bsh_h005_mod_bal_ben_hind_1nm_P1D-m_mf-yyyymm
Expected total, max size of datafile(s) [Gb]:	8 GB
Format	gridded, NetCDF
Partner producer and contact	BSH: Anja Lindenthal (anja.lindenthal@bsh.de), Josefine Hahn (josefine.hahn@bsh.de)
Datasets used for calibration/validation/assimilation	ICES database for oxygen and pH
Method	Coupled NEMO4.2.1-ERGOM forced by ERA5 Meteorology

4.2 H6 Mediterranean Sea

ID dataset	H6
Products names (product IDs)	Bottom Oxygen (7.1); Bottom pH (8.1); Bottom light (9.1);
Name sub-variables	same as above
Geographical coverage	Mediterranean Sea
Horizontal resolution	4.5 km
Vertical resolution	1 level
Time period	1999-2020
Temporal resolution	Daily

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Data-file(s):	Folder: neccton-ogs_h6_mod_med_bot_hind_4.2_km_P1D-m_[yyyymm]
Expected total, max size of datafile(s) [Gb]:	50Gb
Format	NetCDF
Partner producer and contact	Gianpiero Cossarini (gcossarini@ogs.it)
Datasets used for calibration/validation/assimilation	Literature estimates
Method	Coupled OGSTM-BFM-OASIM forced by NEMO ogcm, climatological river inputs

4.2 H40 Black Sea

ID dataset	H40
Products names (product IDs)	macrozoobenthos (12), macroalgae(13), sedimentary rates (14)
Name sub-variables	same as above
Geographical coverage	Black Sea
Horizontal resolution	2.5km
Vertical resolution	Horizontal maps
Time period	2 samples year
Temporal resolution	Annual
Data-file(s):	neccton-uol_h40_mod_blk_ben_hind_2.5km_P1D-m_sf-000
Expected total, max size of datafile(s) [Gb]:	50 Gb
Format	gridded, NetCDF
Partner producer and contact	Quinten Mudde, quinten.mudde@nioz.nl
Datasets used for calibration/validation/assimilation	Copernicus Marine in situ TAC , EMODnet Biolgy
Method	Habitat modelling, DEB model coupled to NEMO-BAMHBI

4.2 H41 Black Sea

ID dataset	H41
Products names (product IDs)	Bottom Light (9.2)
Name sub-variables	same as above
Geographical coverage	Black Sea
Horizontal resolution	15 km
Vertical resolution	59 vertical levels
Time period	Hindcast: 1999-2023
Temporal resolution	daily

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Data-file(s):	neccton-uol_h40_mod_blk_ben_hind_15km_P1D-m_sf-000
Expected total, max size of datafile(s) [Gb]:	100 Gb
Format	gridded, NetCDF
Partner producer and contact	Loïc Macé, loic.mace@uliege.be
Datasets used for calibration/validation/assimilation	Copernicus Marine in situ TAC
Method	Coupled NEMO-BAMHBI forced by MAR atmospheric conditions, climatological river inputs, RADTRANS

4.2 H22 Mediterranean Sea

ID dataset	H22
Products names (product IDs)	Macrozoobenthos (12.1); Benthic flora (13.1)
Name sub-variables	same as above
Geographical coverage	Mediterranean Sea
Horizontal resolution	4.5 km
Vertical resolution	1 level
Time period	1999-2020
Temporal resolution	Yearly
Data-file(s):	Folder: neccton-ogs_h22_mod_med_bot_hind_4.2_km_P1Y-m
Expected total, max size of datafile(s) [Gb]:	2Gb
Format	NetCDF
Partner producer and contact	Vinko Bandelj, vbandelj@ogs.it
Datasets used for calibration/validation/assimilation	GBIF, OBIS, Italian national environmental authorities, other research organizations.
Method	HSM coupled with OGSTM-BFM-OASIM forced by NEMO ogcm, climatological river inputs

5. Concluding remarks

The work will deliver an ambitious total of 29 new model products delivered across 4 Copernicus Marine Service regions. User demand for the new products was documented in both the online and interactive stakeholder surveys. We anticipate some challenges associated with incorporating multiple new developments into existing models; extensive validation against available observations will be critical for assessing the impact of each new development. We expect the new products to benefit work on benthic habitat mapping, carbon budgeting, environmental health assessment, and higher-trophic-level modelling.

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