Project information	
Project full title	EuroSea: Improving and Integrating European Ocean Observing and Forecasting Systems for Sustainable use of the Oceans
Project acronym	EuroSea
Grant agreement number	862626
Project start date and duration	1 November 2019, 50 months
Project website	https://www.eurosea.eu

Deliverable information	
Deliverable number	D9.4
Deliverable title	**Action Progress Report #3**
Description	Report about progress across all WPs and tasks during project month 33-48, going to be used by ISTAB for evaluation of project status and progress
Work Package number	9
Work Package title	Project Coordination, Management and strategic ocean observing alliance
Lead beneficiary	GEOMAR
Lead authors	Nicole Köstner, Toste Tanhua
Contributors	All work package leaders and task leaders
Due date	31.10.2023
Submission date	31.10.2023
Comments	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 862626.

https://doi.org/10.3289/eurosea_d9.4

Action Progress Report #3

Reporting period: 1 May 2022 – 31 Oct 2023

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Glossary

ASV	Autonomous Surface Vehicle
BOOS	Baltic Operational Oceanographic System
BP	Best Practice
CMEMS	Copernicus Marine Environment Monitoring Service
CRL	Commercial Readiness Level
C3S	Copernicus Climate Change Services
EEZ	Exclusive Economic Zone
EFI	Extreme Forecast index
EOOFS	European Ocean Observing and Forecasting System
EOOS	European Ocean Observing System
EOV	Essential Ocean Variable
EPS	Ensemble prediction system
ERIC	Education Resources Information Center
FAIR	Findable, accessible, interoperable, reusable
FOO	Framework for Ocean Observing
GA	General Assembly
GCOS	Global Climate Observing System
GES	Good Environmental status
GNSS-IR	Global Navigation Satellite System Interferometric Reflectometry
GOOS	Global Ocean Observing System
GSA	Geographical Subareas
HELCOM	Helsinki Commission
IC	Initial-condition
IMDOS	Integrated Marine Debris Observing System
IP	Intellectual Property
IPR	IP Rights
KER	Key Exploitable Result

MAG	Metagenomic Assembled Genome
MHW	Marine heat wave
MOOSE	Mediterranean Ocean Observing System for the Environment
NCA	National climate action
OC	EOOS Operations Committee
OCG	Observations Coordinating Group
OSE	Observing System Evaluation
OSPAC	Oceanographic Services at the service of Ports and Cities
OSSE	Observing System Simulation Experiment
PCU	Project coordination unit
PSMSL	Permanent Service for Mean Sea Level
QC	Quality control
RL	Readiness Levels
RMSE	Root mean square error
RRI	Responsible research and innovation
SBEP	EU Sustainable Blue Economy Partnership
SC	EuroSea Steering Committee
SSH	Sea surface height
SST	Sea Surface Temperature
TAOS	Tropical Atlantic Observing System
TRL	Technical Readiness Level
WG	Working Group
WP	Work package

Executive summary

The EuroSea project has been running for 4 years by the writing of this report, and this report covers months 33-48 of the action at a time when most tasks are completed and deliverables submitted. However, a few items still need to be finalized as we have experienced delays for a few items, mostly due to COVID, or Brexit, but we expect all of those to be solved before the end of the project by the end of 2023. The progress of the WPs is summarized below, and is described in more detail in the main part of this report. As an innovation action, EuroSea is keeping a close eye on creating impact and on creating services and products that will last past the lifetime of the project. Therefore, we would like to emphasis the registry of impacts that is published on the EuroSea website[1]. These about 100 areas illustrate the impact that EuroSea has had on improving the European ocean observing and forecasting system. EuroSea has produced a number of targeted services and products for ocean health, operational services and climate, that are tested and used by the stakeholders.

1. EuroSea positioning in relation to other developments and summary of progress

During this reporting period, and indeed during the whole time-period of EuroSea, the importance of sustained ocean observing and forecasting system for societal benefit has been increasingly acknowledged by various stakeholders. Many of which EuroSea has interacted directly with, either regularly of occasionally. EuroSea has interacted with, for instance, the Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC COP), the Group of Earth Observing (GEO) both globally, European, and on national scales. EuroSea is actively supporting and interacting with the Global Ocean Observing System (GOOS), as well as the Ocean Predict program. Importantly, in particularly during this reporting period, EuroSea has connected with and cooperated with a number of the UN Ocean Decade programs and projects. This shows the ambition of EuroSea to act on a global scale, albeit with a focus on the European system and stakeholders.

An important aspect that has developed during this reporting period is the advancement of the Integrated Marine Debris Observing System (IMDOS)[2] where EuroSea played a key role and supported the activities of the International Ocean Carbon Coordination Project (IOCCP) and GEO Blue Planet to reach community consensus of IMDOS – the IMDOS strategy is being finalized as this is written. EuroSea scientists are very active to work with the World Meteorological Organization (WMO) on agreeing on and formulating the strategy for the Global Greenhouse Gas Watch (GGGW), that has the potential to create a step-change in how we observe the ocean surface for CO2, and the results from EuroSea is supporting this process. Similarly, EuroSea scientists are active in the priority areas of the G7 working group Future of the Ocean and the Seas (FSOI), and are actively contributing to that effort.

Overall, EuroSea is well positioned in the European and international landscape for ocean observing and forecasting. We have improved the coordination and harmonization towards an integrated ocean observing and forecasting system. EuroSea has been working closely with end-users and is creating products targeted

[1] https://eurosea.eu/impacts/
[2] https://geoblueplanet.org/integrated-marine-debris-observing-system/

for ports, coastal communities, fisheries, aquaculture and local authorities, work that has come to fruition during this reporting period. Below is an overview of the activities on a work package level. A more detailed report from the work packages is provided later in the main part of this report.

WP1 - Governance and Coordination of ocean observing and forecasting systems

To strengthen the European ocean observing and forecasting system several workshops were organised, discussing foresight, network integration, and community engagement. European Marine Board organised a foresight workshop (March 2023) on the sustainability of the ocean observing and forecasting system gathering key recommendations or considerations for possible future mechanisms to sustainably fund and coordinate ocean observation, prediction and information delivery in Europe. Two OceanPredict/EuroSea workshops were organised (June 2022 and July 2023) to strengthen the linkages of the EuroSea community with the leading edge of global forecast and prediction and to provide insight into the current activities and progress of the development of the ocean information value chain. The Integrated Marine Debris Observing System (IMDOS) was officially launched as a joint initiative of GOOS, GEO Blue Planet and UNEP Global Partnership on Marine Litter during an official UN Ocean Conference side event held in Cascais, Portugal, in June 2022, endorsing the interim Steering Committee and IMDOS Terms of Reference. In April 2023, IMDOS was officially endorsed as a GOOS development project. The International Marine Debris Data Harmonization workshop was held in August 2023 in Yokohama, Japan, resulting in milestone consensus regarding common metadata and data requirements for surface microplastic data reporting globally, adoption of common methods for global monitoring, initiation of a coordinated observing network for microplastics, and a roadmap towards a federated and interoperable global data management system for marine debris. The open-access OBIS BioEco Portal, also hosting the information about existing European biological and ecosystem monitoring programs, was launched (July 2022). The development of the EuroSea best practices continued with a total of four currently completed and still more under discussion. A paper was submitted on "An Observational and Warning System for the Aquaculture Sector" jointly with WP6, which included best practices in the aquaculture sector. Analysis of hard and soft law frameworks and mechanisms to enable adequate adaptation of ocean observing system design at a regional and global level were undertaken. There is planned a continued push for the improvement of the regulatory framework for Europe through awareness creation on the basis of EuroSea reports, articles, briefs and flyers. The EOOS Operations Committee work was progressing, with two meetings held (November 2022 and March 2023). A successful application (AMRIT) together with the Marine Research Infrastructures engaged in the EOOS Operations Committee was prepared to consolidate the Marine Research Infrastructures and develop federated services (including system performance monitoring and reporting, common planning of operations, and traceability of data). The EOOS Strategy 2023-2027 was launched in March 2023, and the Roadmap for Implementation was published, defining the high-level activities around the interconnected objectives. To support the EOOS Strategy implementation, and to facilitate the sustainability of European ocean observations, a list of recommendations was compiled for networks, frameworks, Member States, and the European Commission (D1.8). In addition, a total of 30 thematic gaps were detailed in and classified to cover all field of ocean observations and monitoring related to societal needs. Moreover, a scoring approach was developed, using the Framework of Ocean Observations table in order to evaluate the capacity of the European ocean observing and forecasting system in monitoring the various ocean phenomena. Readiness Levels were assigned to each phenomenon based on the literature review conducted.

WP2 - Ocean Observing System Design

The overarching objective of WP2 was to apply the system design methodologies as delineated within the Framework for Ocean Observing (FOO) to the EuroSea Observing System. This endeavour aimed to bolster

the development of interconnected and integrated European ocean observing systems, particularly catering to the expanse of the wider Atlantic Ocean and the Mediterranean Sea. WP2 leveraged the accomplishments realized under the Horizon 2020 (H2020) framework and sought to perpetuate the legacy of the AtlantOS H2020 project, advancing it within the framework of the Galway and Belém Agreements. The specific objectives of WP2 encompassed: 1) The definition of high-level requirements for EuroSea, premised on societal benefits, with a direct linkage to the societal challenges, endemic to the broader Atlantic and Mediterranean basins, as well as the European Blue Growth Strategy. These requisites were subsequently formulated into strategic recommendations geared towards the sustained monitoring of Essential Ocean Variables (EOVs) and their connection with societal relevant indicators within the scope of LR7 and LR8. This has been formulated in the Deliverable 2.4 and in different scientific publications. 2) The identification of requisites within existent ocean observing networks, designed to support specific demonstration activities (WP5, 6, 7), alongside the provision of diverse operational services encompassing sub-seasonal and seasonal climate forecasts, predictions of extreme events, weekly ocean forecasting, and services in line with Copernicus Marine Environment Monitoring Service (CMEMS). This has been documented in Deliverable 2.4 and related publications. 3) The provision of guidelines aimed at enhancing existing components and/or the integration of new ocean observing elements into the EuroSea framework. This process involved the application of diverse techniques, including Observing System Simulation Experiments (OSSEs) and data assimilation, designed to optimally integrate in-situ and satellite observations with numerical models, thus furnishing precise estimates for the selected indicators. This work has led to the publication of deliverable D2.3 and different scientific papers.

The work undertaken within WP2 was instrumental in directly supporting the activities of the EuroSea Demonstrators (WP5, 6, 7), the integration and enhancement of observing networks (WP3), and data assimilation and forecasting (WP4). Notably, the achievements in WP2 primarily centred on the verification of EOVs and associated indicators, a comprehensive analysis of deficiencies within existing ocean observing systems, as well as the exploration of prospective enhancements and system design aspects. This encompassed the execution of tasks such as task 2.1, which focused on gap analysis within existing systems, and task 2.2 and task 2.3, which entailed system design studies.

WP3 - Network Integration and Improvement

Acknowledging that most European observing networks are designed to deliver towards certain issues aimed at particular stakeholders, but there is low level of integration between networks, delivering towards a wider range of users, a major EuroSea objective has been to improve and integrate observing networks and the data flow by: 1) Improving and enhancing the readiness and integration of observing networks, including thematic networks (augmented observatories) by supporting coordination and increasing the Technical Readiness Level (TRL) of observing systems and tools and data delivery/management. 2) Enabling FAIR data and facilitating integration of data by improving the data management structure and practices of the observing networks, and supporting ingestion of ocean data in the Copernicus Marine Service, EMODnet and SeaDataNet portfolios. 3) Strengthening European visibility and leadership in international ocean observing efforts and foresight at an international level (such as the Global Ocean Observing System [GOOS[3]] and the

[3] https://www.goosocean.org/

Global Climate Observing System GCOS[4]; in particular strengthening the European Ocean Observing System (EOOS[5]) and contributing to the implementation of the GOOS 2030 Strategy.

Towards the above objectives the Framework Processes by Readiness Levels (RL), as outlined in the FOO, was chosen as an appropriate method for examining the RL of the networks represented in WP3. The RL is divided into three main areas: 1) Requirement processes, 2) Coordination of observational elements, and 3) Data management and information products.

For all networks there was an initial (start of EuroSea) and final assessment through an extensive analysis of numerous network attributes. As expected, a wide variability between the different networks was found, which to a large extent depends on their respective maturity level. Thus, "older" networks are generally more organized with a wide range of activities covering many different aspects in contrast to the "newer" networks in which activities are focusing on a small number of priorities. Another important factor is the connection with the corresponding global efforts as it provides an opportunity to share knowledge and gain from acquired experiences. Finally, those networks that include groups that are organized under a legal framework such as an ERIC (Education Resources Information Center) or an AISBL (international non-profit association), have a higher degree of organization exemplifying governance, funding progress on data handling and sharing, providing access to the infrastructure, incentivizing convergence of various documentations on knowledge into Best Practices, etc. as all the components are prerequisites for maintaining an observing infrastructure.

Overall, EuroSea activities had a significant positive impact on all the observing and thematic networks, actively promoting synergies and collaboration, with most of them successfully reaching Framework Processes Readiness Criteria Level 7 and above. Although progress at many different aspects must continue beyond EuroSea, it is important that the framework has been set. It is thus suggested that an annual evaluation/assessment process for each network/task team is adopted within EuroGOOS. By going through this exercise annually, each EuroGOOS Task Team (observing network) will be able to describe its current state, assess progress and most importantly to define next targets and priorities.

WP4 - Data integration, Assimilation, and Forecasting

WP4 completed all remaining tasks and organized the submission of all final deliverables. WP4 has met all the main objectives set at the start of the project. It improved the use and integration of in situ observation data sets in the Copernicus Marine Service modelling and forecasting systems (moorings, gliders, deep and BGC Argo). New ensemble forecasting capabilities have been developed and tested at regional level. This will pave the way for the implementation of operational ensemble forecasts in the Copernicus Marine portfolio (post 2025). Ship-based time series pilot products have been developed and new carbon synthesis products have been delivered. The skill of ocean variables from the Copernicus Climate Change seasonal forecasting systems has been assessed from observations.

WP5 - Coastal Resilience and Operational Services Demonstrator

WP5 aims to demonstrate how observational systems and modelled data can be integrated to provide users with bespoke planning tools. These planning tools (such as the Oceanographic Services at the service of Ports and Cities (OSPAC) software delivered by T5.2.3) may be designed for hazard warning on short timescales, for example for storm surge events, whilst others may be applied to the longer-term hazards presented by

[4] https://gcos.wmo.int/en/home
[5] https://www.eoos-ocean.eu/

sea level rise, as is the case for the Prototype Sea Level Visualization and Planning Tool (T5.1.3) and the Mediterranean Sea Level Reconstruction (T5.1.2).

Deliverables D5.1 (Prototype sea level planning and scenario visualization tool) and D5.5 (Final version of the OSPAC software running operationally for the demonstration) had already been delivered in the previous reporting period, so efforts in respect of these successes were focused upon publicizing the outputs to support WP8. OSPAC was promoted at numerous events including soft and hard launch demonstrations to users in Barcelona, at webinars, at workshops and was the subject of a user feedback exercise, whilst the Prototype Sea Level Visualization and Planning Tool was publicized at the EuroSea Assembly in Cadiz, via press releases by ARUP and the University of Cambridge and through an article in Oceanography magazine.

Task 5.1.2 was completed in this reporting period with the submission of the final deliverable D5.8 on time. The resulting datasets and supporting code were published in an open access forum, so that the technique can be replicated for other ocean regions and on the recommendation of the external reviewers, further work was undertaken to merge and resubmit these deliverables together. Effort was then devoted to the preparation of an associated scientific paper in the Journal of Geophysical Research: Oceans. In support of WP8, a press release was prepared that was reported by 5 different news outlets including the UK Guardian newspaper (circulation ~111, 000).

Although the deliverables associated with task 5.2.1 (Model downscaling) had been submitted in the previous reporting period, work continued to strengthen these on the advice of the external reviewers and D5.3 (CMEMS downscaled circulation operational forecast system) and D5.4 (CMEMS downscaled wave operational forecast system) were resubmitted and the remaining milestone for this task was successfully submitted on time.

Many of the remaining milestones and deliverables for this WP were contingent upon successful installation of tide gauges at the 3 demonstrator sites. These had already been delayed due to the COVID-19 pandemic-related travel restrictions and further numerous delaying factors were encountered in this period. Nevertheless, they did not halt progress and the tide gauges for Barcelona and Taranto are now in-situ, with the Buenaventura tide gauge currently in transit to Colombia. The associated deliverables (D5.6, D5.7, D5.9) and milestones (MS14 and MS24) have been submitted, although some will be updated once the final tide gauge is in-situ. These delays meant that the focus of task 5.1.1 (Low cost and maintenance free tide gauges) was primarily upon delivering the tide gauge installations during this reporting period. Some promotional activity was possible, with poster presentations at the EuroSea General Assembly, 1 national conference (UK Challenger), 1 international conference (IUGG) and an NOC internal conference. The task 5.1.1 leader also contributed a face-to-face interview and written questionnaire response to D8.7 (Lessons learnt on public-private interfaces in European ocean observing).

The delays in task 5.1.1 also cased the postponement of deliverables D5.10 (Final report describing the demonstration and the user feedback at European sites) and D5.11 (Scientific model validation report during the demonstration period), but work is presently underway to complete these before the end of the project.

WP6 - Ocean Health Demonstrator

WP6 activities in the Ocean Health Demonstrator focused on developing a shared understanding of water management among end-users in aquaculture, fisheries, tourism, environmental agencies and scientists by working together to co-create products that help to identify and foresee “Extreme Marine Events'' threatening marine ecosystems, resources, and related businesses, and supporting adaptive management

decisions. WP6 was active in demonstrating the value of observing and forecasting through the development of useful data products and services, promoting Copernicus Marine Service products in fisheries science and developing ocean indicators and tools to support environmental assessments. Co-development was an essential part of all WP6 activities with regular co-developer meetings taking place to exchange knowledge and ensure EuroSea legacy post-project. WP6 partners were actively involved in the development of the "EuroSea Business Plan" and WP6 "Sustainability and Business Plan" (D8.8, D6.5) and a "Best Practice" for an application on "An Observational and Warning System for the Aquaculture Sector". A foundation was created for new market and management opportunities for the private sector (Xylem; Mowi; AVRAMAR – Task 6.1, Task 6.4) through the deployment of data buoys, data delivery in real time, ingestion into Copernicus in situ TAC, and the co-creation of new ocean products (e.g. bespoke alert system for extreme marine events) for aquaculture. Tasks 6.1 and 6.4 partners worked together to deploy, maintain, redeploy (when necessary) the EuroSea data buoys at aquaculture facilities in the north-east Atlantic and the western Mediterranean Sea. A bespoke aquaculture web portal[6] was created after a number of iterations on design and content based on end user feedback and web-based tools were developed to explore EOVs, indicators and marine heat waves (MHWs) and provide alerts. Task 6.1 also produced a white paper on Sargassum. Task 6.2 advanced efforts to connect fisheries science and environmental variable information in the population dynamics models. In particular progress was made on the stochastic modelling to assess external environmental drivers of Atlantic chub mackerel population dynamics, and on disentangling the environmental forcing of the European Hake stocks (Merluccius merluccius; Linnaeus, 1758) in the western Mediterranean. In Task 6.3, significant progress was made to improve the number of near real time ship data assimilated into the Baltic Sea numerical model. Supporting tools were developed for environmental assessments in the Baltic Sea leading to interest from other sea basins to replicate the approach taken. Integrating observations from both the Baltic Operational Oceanographic System (BOOS) and Helsinki Commission (HELCOM) monitoring networks with a reanalysis production tool developed in CMEMS resulted in a more fit-for-purpose operational oceanography system and enhanced environmental assessments in the Baltic Sea.

Overall, notable progress was made in WP6 during the final phase of EuroSea with the submission of seven Deliverables (D6.1, D6.2, D6.3, D6.4, D6.5, D6.6, D6.7), three Milestones (MS22, MS25, MS29) and three internal Milestones (iMS47, iMS50, iMS30).

WP7 – Ocean Climate Indicators

WP7 addresses innovative ways to assess the role of the ocean in Earth's climate through the development, evaluation – including uncertainties - and dissemination of ocean climate indicators and their value for socioeconomic use.

Task 7.1 has evaluated observing strategies and data products needed to determine the economic value of the (variable) ocean carbon sink of European relevant deep convection regions. Particularly, different approaches to value the ocean sink have been demonstrated, comparing a climate-change damage-based approach with an abatement, market-based approach. A high-resolution carbon flux dataset (0.25x0.25 degree) to estimate the ocean carbon sink and source in coastal areas has been used for this purpose. By breaking down the carbon sink by nations Exclusive Economic Zones (EEZ), this task estimated which countries are the largest donors of ocean carbon wealth and which countries would be affected the most if a weakening of the ocean sink would need to be compensated by higher emission reduction levels. Moreover, ocean carbon variability in the interior ocean has been investigated in order to assess the linkage of these

[6] http://eurosea.marine.ie/

processes for the use in national climate action (NCA) plans delivered in the framework of the Paris Agreement. In summary, large-scale connectivity in the ocean does not allow clear delineation of patterns of regional carbon uptake across national boundaries, limiting an assessment of the EEZs in light of NCA plans. A major recommendation from this task is the improvement of carbon sampling in all nations EEZ regions and following global standards and under FAIR principles.

Task 7.2 has published an analysis of societally-relevant predictions of ocean variables and indicators in seasonal forecast systems and has achieved advancements with respect to stakeholder engagement activities. A particular emphasis of the workflow was linked to the indicators describing MHWs, and this task has contributed to unravel approaches for improved prediction skills of marine extremes, leveraging the role of subsurface ocean change to establish a more comprehensive description of these specific changes in the ocean of high socioeconomic relevance. These results have been further supported by outcomes on characteristics of marine heatwaves at EEZ level, further enhancing the recommendation for strengthening surface and subsurface observing systems in most national waters to better establish local-scale risk assessments and to respond to diverse stakeholder needs.

Task 7.3 had its focus on exploring opportunities to further strengthen observing system capacities through optimization tests, including improved quality control approaches. Particularly, the work had been focused on upscaling the spatio-temporal coverage and quality of carbon flux estimates over the tropical Atlantic region. This was being achieved through a Tropical Atlantic Observing System (TAOS) optimization demonstration using an integrative multi-platform approach. The task proceeded while closing observational gaps through an integrative multi-platform approach, bringing together the different strengths from combining various observation techniques. As large amounts of field work had been included, this task has been significantly affected by the pandemic, but a major part could be compensated through successful external additional funding for the ASV mission following the withdrawal of an external partner. Moreover, a consistent and rigorous correction procedure to quality-control and process of the data from the integrated multi-platform approach has been implemented. In addition, the data have been used to apply a neural network approach, and the results emphasize the need for high-quality homogeneously calibrated carbonate variable measurements, which have been demonstrated to be mandatory for computing air-sea CO_2 fluxes at a basin scale from multiple observing platforms.

WP8 - Communication: Engagement, Dissemination, Exploitation, and Legacy

With the completion of many project deliverables and the return of opportunities for more face-to-face interactions, activities in WP8 have also increased. A focus continued to be on disseminating the project and its results and increasing the visibility of the importance of a long-term coordinated, integrated and sustainable ocean observing and forecasting system. A wide variety of tools were used for this purpose, such as website, Twitter, Youtube, workshops, podcast, exhibition, rollups, flyers, etc.

In particular, young people were increasingly addressed in these activities during this reporting period in order to share the project vision with the future generation and to increase their awareness of the existing challenges and potentials. In addition, the demonstrators in particular were supported in planning their communication and exploitation strategies.

WP9 - Project Coordination, Management and strategic ocean observing alliance

EuroSea's management and coordination were good and efficient during this period. Regular coordinative meetings continued as in previous periods. Good communication with the responsible officers at the European Commission was maintained. Internal communication with all task teams was further established

through continued targeted feedback on all submitted documents. Through the increased frequent personal representation of the project and its contents at various international events, the concerns of the ocean observing and forecasting community were shared with many different stakeholders and thus made more visible and heard.

2. Work package progress reports

WP1 - Governance and Coordination of ocean observing and forecasting systems

Lead: IOC-UNESCO, CO-lead: EuroGOOS

Objectives
• Support observing system coordination and governance both on international (e.g. GOOS, JCOMM, GCOS, G7, OceanPredict, and GEO) and at European level in supporting EOOS/EuroGOOS implementation.
• Deliver foresight into societal relevance, drivers and governance for ocean observation systems, new technologies and system sustainability.
• Strengthen the Ocean Observing system, with a focus on European needs, through extending the BioEco networks, monitoring of marine plastics, and supporting delivery for assessments, SDG indicators etc.
• Development of key components of EOOS structure and implementation of the GOOS 2030 Strategy.
• Step change in availability and identification of Ocean Best Practices.
• Support ocean observing status monitoring and visualization.

Summary of progress towards WP objectives

To support observing system coordination and governance both on international (e.g. GOOS, JCOMM, GCOS, G7, OceanPredict, and GEO) and at European level in supporting EOOS/EuroGOOS implementation.

Two OceanPredict/EuroSea workshops were organised (June 2022 and July 2023) to strengthen the linkages of the EuroSea community with the leading edge of global forecast and prediction and to provide insight into the current activities and progress of the development of the ocean information value chain. The EOOS Strategy 2023-2027 was launched in March 2023, and the Roadmap for Implementation was published, defining the high-level activities around the interconnected objectives. The challenges in national, regional and international collaboration and in the overall sustainability of European ocean observing were recognised. To help the sustainability of European ocean observations, a list of recommendations was compiled for networks, frameworks, Member States, and the European Commission.

Deliver foresight into societal relevance, drivers and governance for ocean observation systems, new technologies and system sustainability.

The European Marine Board Secretariat organised a foresight workshop on the sustainability of the ocean observing and forecasting system in March 2023 to gather key recommendations or considerations for possible future mechanisms to sustainably fund and coordinate ocean observation, prediction and information delivery in Europe. Analysis of hard and soft law frameworks and mechanisms to enable adequate adaptation of ocean observing system design at a regional and global level were undertaken. There is planned a continued push for the improvement of the regulatory framework for Europe through awareness creation on the basis of our reports, articles, briefs and flyers.

Strengthen the Ocean Observing system, with a focus on European needs, through extending the BioEco networks, monitoring of marine plastics, and supporting delivery for assessments, SDG indicators etc.

The open-access OBIS BioEco Portal, hosting also the information about existing European biological and ecosystem monitoring programs (including the BioEco monitoring programs information compiled during the last reporting periods), was launched in July 2022. A review paper on zooplankton observing capabilities was published in Nature Communications in February 2023.

The Integrated Marine Debris Observing System (IMDOS) was officially launched as a joint initiative of GOOS, GEO Blue Planet and UNEP Global Partnership on Marine Litter (GPML) during an official UN Ocean Conference side event held in Cascais, Portugal, in June 2022, endorsing the interim Steering Committee and IMDOS Terms of Reference. Regular meetings of the IMDOS Steering Committee were held on a bi-monthly basis. In April 2023, IMDOS was officially endorsed as a GOOS development project. The International Marine Debris Data Harmonization workshop was held in August 2023 in Yokohama, Japan, resulting in milestone consensus regarding: common metadata and data requirements for surface microplastic data reporting globally, adoption of common methods for global monitoring, initiation of a coordinated observing network for microplastics, and a roadmap towards a federated and interoperable global data management system for marine debris. IMDOS visual identity, social media communication channels and website were developed.

Development of key components of EOOS structure and implementation of the GOOS 2030 Strategy.

The EOOS Operations Committee (OC) work was progressing, with two meetings held during the reporting period (November 2022 and March 2023). A successful application together with the Marine Research Infrastructures engaged in the EOOS OC was prepared to consolidate the Marine Research Infrastructures and develop federated services (including system performance monitoring and reporting, common planning of operations, and traceability of data).

Step change in availability and identification of Ocean Best Practices.

The development of EuroSea best practices continued with a total of 4 currently completed and still more under discussion. A paper was submitted on "An Observational and Warning System for the Aquaculture Sector" jointly with WP6, which included best practices in the aquaculture sector.

Support ocean observing status monitoring and visualisation.

Task 1.2 was completed in the last reporting period.

Gap analysis of European Ocean Observing System.

A total of 30 thematic gaps are detailed in and classified based on the Good Environmental status (GES) of the MSFD, the phenomena and threats of Copernicus, and key components of the value chain, in order to cover all field of observations and monitoring related to societal needs. Moreover, a scoring approach has been developed, using the FOO table in order to evaluate the capacity of the European Observing and forecasting system in monitoring the various ocean phenomena. Readiness Levels were assigned to each phenomenon based on the literature review conducted.

Detailed progress per task (or subtasks)

Task 1.0: Coordination

Task leader: EuroGOOS, Partners: IOC-UNESCO

WP1 team online meetings have been held to discuss activities, actions and planning of next steps, plus additional topical task meetings as required. The meetings have been helpful by providing a good overview of the teams' activities and finding opportunities to collaborate and support.

Task 1.1: Observing and forecasting system coordination, national, regional, global

Subtask 1.1.1 EOOS GOOS Implementation

Task leader: EuroGOOS, Partners: IOC-UNESCO

The EOOS Strategy 2023-2027[7] was prepared with the broad consultation of the ocean observing community - EOOS governance structures, EuroSea Steering Committee, EuroGOOS Board, EC DG MARE. The Strategy was complemented by the Roadmap for Implementation[8] describing the high-level activities of interconnected objectives. The EOOS Strategy 2023-2027 was launched in March 2023 and has been broadly introduced at different meetings to a wide range of stakeholders since then. The EOOS Operations Committee (OC) work was progressing, with two meetings held during the reporting period (November 2022 and March 2023) to discuss the priority actions on 'Improving the ocean observing system implementation into the coast' and 'Development of mechanisms for information and knowledge exchange (best practices, case studies, success stories)' and the ongoing and pending Actions of the Committee. The organisation of the upcoming OC meeting is in progress. A successful application together with the marine research infrastructures engaged in the EOOS OC was prepared (AMRIT - Advance Marine Research Infrastructures together) to consolidate the marine research infrastructures and develop federated services (including system performance monitoring and reporting, common planning of operations, and traceability of data). AMRIT will provide a catalyst for the development and consolidation of marine research infrastructures throughout Europe, providing a benchmark for operational coordination and collaboration. AMRIT will advance EOOS in line with its 2023-2027 Strategy and beyond, and the European Commission's ambitions for sharing responsibility in ocean observing across Europe. The challenges in national, regional and international collaboration and in the overall sustainability of European ocean observing were recognised. To help the sustainability of European ocean observations, a list of recommendations was compiled for networks, frameworks, Member States, and the European Commission (deliverable D1.8).

Subtask 1.1.2 Strengthen and extend BioEco monitoring networks throughout the European Seas

Task leader: IOC-UNESCO

The open-access GOOS BioEco Portal[9], hosting also the information about existing European biological and ecosystem monitoring programs (information compiled during the last EuroSea reporting periods), was launched in July 2022. The portal offers an interactive map, metadata, and spatial information of global ocean observing programs that monitor biological and ecosystem EOVs. With the contribution of the EuroSea project, a total of 296 unique marine monitoring programs dedicated to observing at least one BioEco EOV within European waters were identified. Leveraging EuroSea survey results, we reach out to the global zooplankton community to enhance our understanding of this EOV's observational capabilities. We successfully collaborated with a global team of ecologists, biogeochemists, modellers, and managers to 1) summarise our current knowledge of zooplankton in a changing climate, 2) identify critical knowledge gaps, 3) catalogue worldwide monitoring programs, 4) assess data availability from these programs, 5) develop an

[7] https://www.eoos-ocean.eu/approach/strategy-and-implementation/
[8] https://www.eoos-ocean.eu/approach/strategy-and-implementation/
[9] https://bioeco.goosocean.org/

integrated observation program tailored to user needs. Our comprehensive review paper was published in Nature Communications[10], a high-impact journal, in February 2023. Additionally, during the EuroSea General Assembly and Symposium in September 2023, the GOOS BioEco Panel held a hybrid meeting, fostering valuable face-to-face interactions with various stakeholders. This engagement ensures the long-term impact of EuroSea project outcomes, particularly in the realm of biological ocean observations. This will be further bolstered by discussions held and coordination with emerging European Horizon projects.

Subtask 1.1.3 Developing capacity and coordination for a sustained ocean observations of marine plastic contaminants

Task leader: IO PAN

The Integrated Marine Debris Observing System (IMDOS) was officially launched as a joint initiative of GOOS, GEO Blue Planet and UNEP Global Partnership on Marine Litter (GPML) during an official UN Ocean Conference side event[11] held in Cascais, Portugal, in June 2022. The event, jointly organised and sponsored by EuroSea and EU4OceanObs, among others, was attended by over 80 stakeholders from around the world, including representatives of UN agencies and ministries. The IMDOS interim Steering Committee and initial IMDOS Terms of References were publicly endorsed. In September 2022, the current status of IMDOS implementation and its role in monitoring marine litter pollution was presented at the 7th International Marine Debris Conference (7IMDC) in Busan, Korea. Several IMDOS Steering Committee meetings have been organised online since then, focused on developing the IMDOS Strategy and Implementation Plan documents. Efforts to coordinate global marine debris data harmonisation were significantly enhanced by adopting the leading role in the UNEP GPML Community of Practice on Data Harmonization, Ocean & Coasts Domain, as well as through partnership with the Ministry of Environment Japan, EMODnet Chemistry in Europe and NOAA NCEI in the US among others. In April 2023, IMDOS was officially endorsed as a GOOS Development Project during the GOOS Steering Committee meeting in Halifax, Canada. In August 2023, EuroSea co-organised and co-sponsored an International Marine Debris Data Harmonization workshop[12] in Yokohama, Japan, which gathered over 40 world-leading experts in marine debris monitoring and data management, and which achieved milestone consensus regarding: common metadata and data requirements for surface microplastic data reporting globally, adoption of common methods for global monitoring, initiation of a coordinated observing network for microplastics, and a roadmap towards a federated and interoperable global data management system for marine debris. In October 2023, advice on harmonisation and standardisation of marine debris monitoring was provided during the H2020 EUROqCHARM Final Conference[13], held in Brussels, Belgium. In May 2023, IMDOS visual identity was designed and social media communication channels were established. A dedicated IMDOS website, including a directory of marine debris monitoring initiatives, has nearly been completed.

Subtask 1.1.4 Ocean Best Practices

Task leader: IEEE, Partners: IOC-UNESCO, SOCIB

The development of EuroSea best practices continued with a total of 4 currently completed and still more under discussion. The Ocean Best Practice System (OBPS) Repository provides the ocean community with an open access, full text archive of methodological documents, multimedia files and other digital records which

[10] https://www.nature.com/articles/s41467-023-36241-5
[11] https://www.eu4oceanobs.eu/marine-litter-monitoring-to-inform-action/
[12] https://geoblueplanet.org/international-marine-debris-data-harmonization-workshop/
[13] https://www.euroqcharm.eu/en/calendar/euroqcharm-final-conference

either serve as best practices or are intended to be their precursors, and addresses the task 1.1.4 requirement to improve the discovery and access for the EuroSea Community to ocean practices. At the start of EuroSea, OBPS contained 890 methodologies and it now has 2023. Not all 2023 methodologies are from European Programmes, but the repository continues to build a European Project Practices Collection presently with 119 methodological documents. From the experience of the successful Endorsement Process piloted by GOOS, where 9 practices (and more in the pipeline) have been endorsed by GOOS Expert Panels, OBPS is now looking to a broad range of international organizations to support and expand the Endorsement Process.

A peer reviewed paper was submitted on "An Observational and Warning System for the Aquaculture Sector'' jointly with WP6, which includes best practices in the aquaculture sector. This task has focused, in part, on working with the modelling and forecasting community to create a culture of best practices for improved interoperability. This includes contributions to the creation of a community-wide assessment of the status and gaps of forecasting and a workshop on standards and best practices for ocean forecasting, which was held at Mercator Ocean International (MOi) in September 2023. Other contributions, while not quantitative, include facilitating continued growth of the recognition of best practices contributing to the social and cultural change in valuing best practices. For example, the task organized the OceanPractices OBPS Workshop VI[14], (October 2022) and the OBPS Workshop VII[15], (September 2023) and contributed to a session on best practices at the EuroSea/OceanPredict 2nd Workshop [16](July 2023), which provided insight into the current activities and opportunities for the development of best practices across the ocean information value chain. The acknowledgement of best practices and their importance was noted by Vladimir Ryabinin, Executive Secretary of the IOC in his presentation at the EuroSea special event 'EuroSea Symposium on Ocean Observing and Forecasting', September 2023.

Subtask 1.1.5 Strengthening links to the leading edge of global forecast and prediction

Task leader: MetOffice

This task linked EuroSea with the international activities of the international science programme for the development and advancement of regional and global operational ocean predictions (OceanPredict) to facilitate knowledge transfer and explore synergies from ongoing complementary activities. Two dedicated workshops provided opportunities for detailed communication regarding the establishment and improvement of EOOS and its role within the operational oceanography value chain. Workshops provided a platform for intense communication and led to a list of recommendations in support of sustaining the ocean observing system and better community collaboration. This task also opened connections of EuroSea with the efforts initiated through the UN Decade of Ocean Science for Sustainable Development, like the SynObs project[17] and the Ocean Prediction Decade Collaborative Centre[18].

The main objective of the EuroSea/OceanPredict 1st Workshop [19](June 2022) was to strengthen the linkages of the EuroSea community with the leading edge of global forecast and prediction through representatives of the OceanPredict community and other international research efforts. The focus on observation and ocean

[14] http://dx.doi.org/10.25607/OBP-1903

[15] https://www.oceanbestpractices.org/community-engagement/workshops/ocean-practices-obps-workshop-vii-09-13-oct-2023-online/?preview_id=1873&preview_nonce=7965d38918&_thumbnail_id=-1&preview=true

[16] https://oceanpredict.org/archived-events/eurosea-oceanpredict-workshop-2/#section-eurosea-overview

[17] https://oceanpredict.org/synobs/#section-overview

[18] https://oceandecade.org/actions/decade-collaborative-centre-for-ocean-prediction-dcc-op/

[19] https://oceanpredict.org/archived-events/eurosea-oceanpredict-workshop-june-2022/#section-home

prediction efforts in a global context showed the importance of international collaboration when planning to improve and advance the observing system and prediction system capabilities. A round table discussion which reflected on the workshop presentation highlighted the need for better communication and closer collaboration of the observation and prediction communities, the importance of involving intermediate and end-users in questions of ocean observations, the consideration of a fully integrated ocean observing system (including all regions and observation types), the plan to create a full ocean information value-chain (from user needs to observations, data assembly and distribution, ocean prediction and services to user and societal benefits) and the value of defining and describing all processes involved in operational oceanography through ocean best practice methodology. The workshop report[20] is available online.

The EuroSea/OceanPredict 2nd Workshop (July 2023) provided insight into the current activities and progress of the development of the ocean information value chain. It has become clear that the community approach of connecting ocean information value chain components into an integrated structure by improving communication and interaction, with a strong emphasis on ocean best practice, is the future for operational oceanography. The EuroSea project had already recognised this when it set up its work packages resembling some of the value chain components and encouraged interdisciplinary exchanges. It must also be emphasised that the initiation of the UN Decade for Ocean Science during the time of the EuroSea project strongly supports better collaboration and interaction with everyone engaged in ocean science. The second workshop ended with a panel discussion focusing on the present value chain status, gaps and issues and future developments. The main suggestions and recommendations for progress included:

- Improvement to the ocean observing system by:
    - Creating a sustained funding mechanism for ocean observations contributing to the sustained ocean observing system by observations of EOVs
    - Increasing ecological and biological observations
    - Setting up a rolling review of requirements for the improvement of the ocean observing system
- Improvement of operational prediction systems by:
    - Implementing digital twin set ups
    - Defining an operational readiness level
    - Setting up observing system experiments and system assessments operationally
- Improvement to ocean product user experience by:
    - Developing ways to deliver ocean product confidence
    - Setting up feedback loops with users to learn of ocean product performance and requirements
- Setting up the ocean information value chain by:
    - Developing good relationships between value chain components
    - Working interdisciplinary and reaching out to social science and economics
    - Using the increasing visibility and relevance of the ocean to develop links with industry (e.g tap into private data to make a case for a data marketplace)
- Ocean best practice

[20] https://oceanpredict.org/docs/Documents/Projects/EuroSea/WS1/Report/EuroSea-OceanPredict-Workshop-June2022-Report-final.pdf

- Setting up a Federated Network for the approval, distribution, application and community-based repository of ocean best practice

Task 1.2: Observing system status monitoring
Task leader: IOC-UNESCO

This task was already completed in the former reporting period.

Task 1.3: Foresight
Task leader: EMB, Partners: EuroGOOS, IOC-UNESCO, GEOMAR

Subtask 1.3.1 Identifying existing initiatives in foresight in ocean observation, emerging strategies and roadmaps
Task leader: EMB

This task was already completed in the first reporting period.

Subtask 1.3.2 Foresight workshop 1: Ocean technology, platforms and Artificial Intelligence
Task leader: EuroGOOS, EMB

This task was already completed in the second reporting period.

Subtask 1.3.3 Foresight workshop 2: Sustainability of the Ocean Observation system
Task leader: EMB, Partners: IOC-UNESCO

During this reporting period, this task continued with the planning of the workshop discussing the sustainability of the Ocean Observation system to take place in Autumn 2022 or Winter 2023. This process was informed by EuroSea partners from WP1 and other WPs, which included a dedicated workshop at the EuroSea Annual Meeting on 10 May 2022 at University Campus in Cádiz, Spain. During this internal workshop, there was a general agreement to focus the theme of the foresight workshop on the impacts of climate change, and to invite representatives of national observing systems, as these actors are responsible for a large part of the sustainability of the ocean observing system. During the summer and Autumn of 2022, the task was in contact with the French and Swedish representatives at the Working Party on Maritime Issues from the Council of the EU. France (July-December 2022) and Sweden (January-June 2023) were the Chairs of the Working Party in charge of negotiating on behalf of the Council of the EU the potential "Ocean observation – sharing responsibility" initiative. Considering the delays with the launch of this initiative, the organisation of the workshop was postponed to Spring 2023 in the hope that an official communication from the European Commission on this initiative would be out.

The foresight workshop on the sustainability of the ocean observing and forecasting system was held on 15-16 March 2023 at the Museum of Natural Sciences, Brussels (Belgium). The organisation of the workshop was supported by Emma Heslop (GOOS, partner IOC/UNESCO) and other WP1 partners. The workshop aimed to gather key recommendations or considerations for possible future mechanisms to sustainably fund and coordinate ocean observation, prediction and information delivery in Europe. These would inform a report on recommendations to the EOOS Framework to be delivered at the end of the EuroSea project.

The workshop was by invitation only and from the nearly 100 invitations, the final participants included representatives of the EOOS Resources Forum and Operations Committee from Belgium, Estonia, Germany, Norway, Sweden and United Kingdom, the European Commission, the G7 Future of the Seas and Oceans Initiative and the EU4OceanObs initiative, UNESCO-IOC GOOS, EuroGOOS, and other EuroSea project

partners. The workshop was moderated by Sheila Heymans, Executive Director of the European Marine Board, and counted with the participation of the President of the Working Party on Maritime Issues Mattias Rust, representing the Swedish Presidency of the Council of the EU, which set the scene with a thought-provoking talk. The rest of the workshop was animated by four discussants who described issues such as, the legal barriers to ocean observing (Erik van Doorn, partner GEOMAR), funding and sustainability challenges (Vicente Fernández, partner EuroGOOS, and Edward Hill, partner NOC) and the societal value of ocean observing (Emma Heslop, partner UNESCO-IOC GOOS). The report from the workshop is available on the EuroSea website[21] and was published in early June 2023 with the media release supported by the GOOS communication officer. The main recommendations coming out of this workshop are included in the WP1 final deliverable D1.8. The outcomes of this workshop were also presented at the workshop on ocean observation of the EU Sustainable Blue Economy Partnership on 27 September 2023 (Brussels, Belgium). As the EU Sustainable Blue Economy Partnership (SBEP) is expected to deliver on the European Ocean Observing System (EOOS) and the Digital Twin of the Ocean, this workshop was driven by the question of how the ocean observation value chain can support and be supported by the blue economy.

Task 1.4: Legal aspects of ocean governance and impact on the observing system

Task leader: GEOMAR, Partners: EMB

Time period: 1 May 2022 – 31 October 2023

For this task, no significant implementation risks occurred in this reporting period. The European Commission's response to its ocean observation initiative has been delayed, but that has resulted in more time to be well-prepared for when the Commission's plans will be known.

Analysis of hard and soft law frameworks and mechanisms to enable adequate adaptation of ocean observing system design at a regional and global level were undertaken. This encompasses the analysis of a multitude of documents that might be legally binding or not. Examples on the international level are the 1982 United Nations Convention on the Law of the Sea, the 1992 United Nations Framework Convention on Climate Change and the 1992 Convention on Biological Diversity. Subsequent agreements to these conventions, also in the form of resolutions and outcomes of expert bodies, are scrutinised. Furthermore, the involvement of international organisations like the World Meteorological Organization and UNESCO's Intergovernmental Oceanographic Commission (IOC) is part of the analysis. Part of this work was presented at the United Nations in June 2022, first in New York[22] and later that month at the UN Ocean Conference in Lisbon. A publication on this topic is currently in preparation.

On a regional level, the assessment concentrated on the work of the European Union, especially on instruments such as the Marine Strategy Framework Directive and the Common Fisheries Policy, but also instruments focusing on the reduction of anthropogenic climate change. Finally, part of the analysis focuses on the usefulness of all these instruments for currently used instruments and platforms for marine scientific research. This work was presented and discussed at the foresight workshop in Brussels in March 2023, organised by colleagues from the European Marine Board. A publication on this topic is currently in preparation.

[21] https://eurosea.eu/new/how-would-the-european-ocean-observing-and-forecasting-system-look-like-in-2035/

[22] http://documents-dds-ny.un.org/doc/UNDOC/GEN/N22/401/74/PDF/N2240174.pdf?OpenElement, paras. 33-59

Following up on the work listed above, there will be a continued push for the improvement of the regulatory framework for Europe through awareness creation on the basis of our reports, articles, briefs and flyers. The task team strives for increased communication with consecutive chairs of crucial bodies involved in the decision-making within the Council of Ministers. This will likely continue beyond the end of EuroSea.

Regular contact with the European Commission / DG MARE, UNESCO's Intergovernmental Oceanographic Commission and the Surface Ocean - Lower Atmosphere Study international research project was established.

Task 1.5 Gap analysis of European Ocean Observing System

Task leader: GEOMAR, Partners: IOC-UNESCO, EuroGOOS

In general, the implementation of this task went smoothly with no significant technical issues or delays. A "Report on gaps in the European Ocean Observing and Forecasting System" (deliverable D1.9) is about to be finalised. Several fruitful in-person discussions and positive feedback on the developed scoring approach of the European Ocean Observing and Forecasting System (EOOFS) presented at the EuroSea Final General Assembly, lead to the incorporation of the results of the scoring approach developed in this task to the report.

The adopted methodology has been tailored in order to systematically identify gaps in the EOOFS and to give actionable recommendations accordingly. Key literature sources were identified to map thoroughly the literature, tackling projects, reports, peer-reviewed articles, and data portals. Moreover, gaps and recommendations have been extracted while attending specialised workshops and meetings during which various key actors of the EOOFS community were present.

This task clearly highlights the most critical weaknesses in the physical, chemical and biological components of the EOOFS, in addition to critical elements of the value chain such as data FAIRness, data policies, observational networks, interdisciplinarity, technology, satisfaction of end-users, coordination and management. Some of these gaps are related to technological advancements while others are caused by the lack of coordination, management and cooperation between different entities. In this task, the gaps identified for each type of observation and every phenomenon/threat observed by EOOS are sometimes very specific, and thus need to be tackled in a targeted way to optimise their observations and improve the efficiency of the EOOS in monitoring these threats. Standards and best practices should be updated for many EOVs. Also, marine policies and legislations, public awareness and users' satisfaction should be better prioritised in the EOOS value chain.

More specifically, a total of 30 thematic gaps are detailed in D1.9 and are classified based on the Good Environmental status (GES) of the MSFD, the phenomena and threats of Copernicus, and key components of the value chain, in order to cover all field of observations and monitoring related to societal needs. Gaps are related to the following phenomena: biodiversity and non-indigenous species, food webs, eutrophication, ocean warming, ocean acidification/ocean carbon, ocean deoxygenation, non-carbon GHGs, contaminants, plastic pollution, sea level rise, Sea ice, coasts, river inputs, marine protected areas, oil leakage, sea floor integrity/bathymetry, wind farms/energy, underwater noise, human activities, and geohazards. In addition, other aspects of the value chain have been assessed to highlight their weaknesses and provide recommendations to address them, such as: the interdisciplinarity of observations, Modelling, technology, research and development aspects, observing networks, data availability/accessibility/FAIRness, Standards/Best practices, marine legislations, sustainability of observations, users' satisfaction, coordination/management/reporting, and literacy.

Moreover, a scoring approach has been developed, using the FOO table in order to evaluate the capacity of the European Observing and forecasting system in monitoring the various ocean phenomena. Readiness Levels (RLs) were assigned to each phenomenon based on the literature review conducted in this task. In addition, and in order to be more inclusive and objective, the scoring approach has been shared with the EOOFS community to get feedback and scores. Thus, the RLs stated in the report are based on the community feedback as well. This proposed approach helps better track the gaps in the value chain, and might be a spin-product that can be used to evaluate the improvement of the observation and forecasting system to take more efficient actions in addressing the gaps and overcoming challenges in the EOOFS. The recommendations provided in deliverable D1.9 are therefore related to the gaps extracted and can be very helpful to improve the EOOFS RLs, if addressed timely.

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
EU4OceanObs	• 2022 UN Ocean Conference Official Side Event "A global instrument to tackle global pollution", June 2022, Cascais, Portugal. • Establishing the global coordination and communication project office for the Integrated Marine Debris Observing System (IMDOS) • International Marine Debris Data Harmonization Workshop, August 2023, Yokohama, Japan.
Ministry of Environment Japan, H2020 EUROqCHARM	• International Marine Debris Data Harmonization Workshop, August 2023, Yokohama, Japan.
UNEP GPML	• 2022 UN Ocean Conference Official Side Event "A global instrument to tackle global pollution", June 2022, Cascais, Portugal. • The 7th International Marine Debris Conference (7IMDC) Technical Session "Integrated Marine Debris Observing System" (20 September 2022, Busan, Republic of South Korea)

Achieved main results

Deliverables		
D1.4	Report on European BioEco networks	✓
D1.6	Maps and metrics on observing systems and metadata	✓
D1.7	Report on the use of legal frameworks for OOSS	✓
D1.8	Final Report of EOOS Implementation Plan	✓
D1.9	Report on gaps in the European Ocean Observing and Forecasting System	Final review ongoing
Milestones		
MS26	Report on marine plastic contaminant monitoring	✓
Internal Milestones		
iMS24.3	EOOS - Advisory Committee Meeting and report	✓
iMS32.2	Report on facilitation of knowledge transfer between EuroSea and OceanPredict	✓
iMS36	Foresight Workshop Report 1: Ocean technology, platforms and Artificial Intelligence.	✓

iMS52	Foresight Workshop Report 2: Sustainability of the Ocean Observation system	✓
Others (optional)		
Legacy	Report from foresight workshop on ensuring accurate climate related predictions in Europe in 2035[23]	✓

[23] https://www.marineboard.eu/publications/report-foresight-workshop-ensuring-accurate-climate-related-predictions-europe-2035

WP2 - Ocean Observing System Design

Lead: CSIC, CO-lead: ENS

Objectives
• Apply the systems design processes of the Framework for Ocean Observing (FOO) on the EuroSea observing system in support of connected and integrated European Ocean Observing systems for the broader Atlantic Ocean and Mediterranean Sea.
• Define the high-level requirements of EuroSea based on the societal benefits, providing a direct link to societal challenges related to the larger Atlantic and Mediterranean basins and the European Blue Growth strategy. These requirements will be translated into strategic recommendations about sustained monitoring of EOVs and linked with LR7 and LR8 societal relevant indicators.
• Identify the requirements in existing observing networks in support of specific demonstrators (WP5,6,7).
• Deliver guidance to improve existing elements and/or implement new ocean observing components to EuroSea using various techniques, including OSSEs and data assimilation to optimally merge in-situ and satellite observations with models to provide accurate estimates for indicators.

Summary of progress towards WP objectives

Task 2.1 has the objective of developing indicators for observing system networks (WP3), demonstrators (WP5-7) and verification of forecasts (WP4). During the last period we have consolidated the list of indicators across the wide range of stakeholders and end-user groups represented within WP4-7 that we co-defined in the initial period of the project. This has been achieved by conducting additional but more focused discussions through general meetings and surveys with the different groups. The process has led to a better understanding of the stakeholder group requirements in terms of indicators and associated EOVs/ECVs. The achievements have been provided as a milestone (MS10). As not all indicators had simple metrics or were clearly defined, we undertook a specific study on one of such indicators, the Marine Heat Waves (MHWs). This study is now achieved and we have been proposing an approach to the larger community to unify and simplify the indicator that is more robust. It also includes a solution for bridging the large (basin) to the local scales. The study and its results have been published in two papers, Dayan et al., 2022 and 2023. This task has been finalized and the overall task achievements have been provided as a deliverable (D2.4).

Task 2.2 has the goal to deliver objective guidelines to improve existing elements and/or implement new components of the Atlantic and Mediterranean Sea Observing system. The general approach is based on Observing System Design Experiments that rely on physical and BGC models, or statistical techniques that realistically represent the space-time variability of the EOVs to be observed, both methods optimally merge in situ and satellite observations. During this period the OSSEs have been performed. Their analysis shows how evolution of the Argo and mooring network benefit to the global system at ¼° corresponding to the future CMEMS global system at 1/12°. This task has been finalized and the overall task achievements have been provided as a deliverable (D2.2).

Task 2.3 has the objective to improve the design of multi-platform experiments aimed to validate the SWOT[24] satellite observations with the goal to optimize the utility of these observing platforms. OSSEs have been conducted to evaluate different configurations of the in situ observing system, including rosette and underway CTD, shipborne ADCP, velocities from surface drifters, and conventional satellite nadir altimetry. Simulations from high-resolution models have been used to simulate the observations and the "ocean truth" to represent fine-scale sea level and surface ocean velocities. Different methods have been tested to reconstruct the simulated observations: spatial and spatio-temporal optimal interpolations, data assimilation and machine learning techniques. The capacity of the reconstructed fields to represent the sea level and surface current variability of the nature run models at the scales and with the expected accuracy of the future SWOT satellite mission have been evaluated considering different configurations of in situ observations. This task has been finalized and the analysis of the results are described in deliverable D2.3.

Detailed progress per task (or subtasks)

Task 2.0: Coordination

Task leader: CSIC, Partners: ENS

Time period: May 1, 2022 - October 31, 2022

As part of the coordination activities, WP2 organized two online meetings with the task leaders. In the first meeting each task presented the activities foreseen in the DoA and those completed, the problems encountered and the mitigating actions taken, as well as the activities planned for the next period. Special attention was given to the delayed activities. The second meeting was used to finalize the project activities. This was followed by a discussion on recommendations for future integration across Europe, taking into account EuroGOOS, EOOS and infrastructure-like activities, as well as global initiatives such as GOOS, SWOT and the UN Ocean Decade observing programs.

Task 2.1: Developing Indicators for observing system networks/Demonstrators

Task leader: ENS, Partners: CSIC

Time period: 1 May 2022 – 31 October 2022

Following the initial task plan, the WP2 team has been working with the following WPs to consolidate the indicators for the different stakeholders and end users of ocean information represented in EuroSea: WP3 (Network Integration and Improvement), WP4 (Seasonal forecasts), WP5 (Coastal Resilience and Operational Services), WP6 (Ocean Health), and WP7 (Climate).

To do so, different steps were conducted: WP2 organised separate meetings with each WP to re-assess the definition of the set of indicators initially designed during the first 18 months of the project (for some of the WPs the concept of indicator versus EOVs/ECVs was relatively clear, for others it was not the case). Next, for indicators in each WP, WP2 discussed and co-defined the requirements in terms of spatio-temporal extent and resolution and, when possible, in terms of accuracy. They then defined the EOVs/ECVs sets associated with each indicator and their requirements. Some of these requirements are associated directly to observed EOVs/ECVs, but most of them are related with analyses, reanalyses or forecasts products. Hence, the definition of requirements in terms of observed EOVs/ECVs is less straightforward. WP2 has organised

[24] https://swot.jpl.nasa.gov/

additional meetings with the OceanPredict community that started during the OceanPredict-EuroSea 2022 Workshop as well as with WPs 4-7 to better assess the observing system capabilities in delivering indicators defined via numerical analyses, reanalyses and forecasts. Indeed, improvement in the skill of these indicators is not entirely linked with the distribution of observations but also with new developments in modelling and data assimilation. Pathways in how to assess more quantitatively the impact of observations on these indicators should be developed via OSEs and OSSEs. Whereas, such exercise goes well beyond the various OSSEs assessments funded in EuroSea, WP4 (Balmaseda et al., in prep) showed sizable impacts of the Atlantic observing system elements on the skill of Seasonal Forecasts for the Atlantic basin but also at the world scale. Moreover, during the recent Climate Observation Conference organised by the Global Climate Observing System programme in Darmstadt, Germany (17-19 October 2022), some contributions showed the impact of observing elements other than Argo floats on WP7 topics (as, for example, the Ocean Heat Content estimates: Cheng et al., in prep.).

WP2 has taken additional actions to provide a legacy for EuroSea. Within the UN Decade of Ocean Sciences and the GOOS Ocean Observing Co-Design Program, they have included some of the EuroSea case studies as specific themes that the program will address in the first 3 years of its implementation (MHWs, Marine Ecosystems, Ocean Carbon) and this across the different EuroSea stakeholders and end-users (including seasonal forecasting, climate indicators and ocean health). This program focuses on co-design to deliver a fit-for-purpose observing system. A strong partnership has been developed between Ocean Observing Co-Design and the SynBios UN Decade of Ocean Science project of the ForSea program, with the aim of carrying out appropriate OSSEs. The indicator development started within EuroSea has led to a strong partnership across the GOOS panels (and beyond) to co-develop science-based indicators that respond to different societal needs (from climate change assessments, to indicators focused on mitigation and adaptation, to assessments of marine life). This will help to bridge evolving societal needs with the observing system needed to address them.

WP2 acknowledges that the requirements in terms of EOVs/ECVs assessed in EuroSea in relation to EuroSea indicators for observing system networks are not fully scientifically satisfying, as this would have required the implementation of OSEs and many more OSSEs than those designed and implemented in EuroSea. In particular, this would have required the development of dedicated regional OSEs and OSSEs relevant to the different EuroSea indicators. This approach, started within EuroSea in task 2.3, has been proposed for implementation within the Ocean Observing Co-Design UN Ocean Decade program in collaboration with SynBios as a legacy of EuroSea.

The needs for indicators among the different EuroSea stakeholders and end-user groups are very different, even for the same indicator such as "sea level" or "sea surface temperature". In fact, some stakeholders assess such indicators at the scale of an ocean basin or marginal sea, provided on a monthly basis, while many end-users are interested in a more regional, if not local, assessment of the same indicators, provided on a daily basis. Also, some end users have a slightly different "definition" or "expectation" of the same indicator (for example, with respect to upper ocean temperature, marine farmers or fishermen are more interested in the temperature at 20 m depth rather than the sea surface temperature).

To begin to respond to such end-user needs, we have developed a new approach in task 2.1 that encompasses the requirements of WPs 4-7 in terms of MHWs. Indicators of MHWs are not yet homogeneous or standardised across the scientific community. Moreover, they are relatively complex as they are defined by different metrics (such as MHW intensity, number, duration, etc.). Also, the same indicator name is used for basin-scale events as well as more regional and local declinations, but there are currently no direct links

in the definition of the two. Finally, MHWs are generally defined in terms of Sea Surface Temperature (SST) EOV/ECV, whereas end users need Subsurface Temperature EOV/ECV at different depths, ranging from 20 m to 200 or even 600 m, depending on the user (aquaculture, fisheries, climate assessment, seasonal forecasting). In fact, MHWs are phenomena that are not exclusively limited to the first few metres of the water column. The work undertaken in this framework is to reconcile MHWs' metrics and scales by making some choices in terms of index definition and requirements. Among different metrics, we have also explored how to include the subsurface expression of these phenomena and derive a well-documented and easily generalised indicator of MHWs to be used in CMEMS or by national/local operational agencies after the completion of the EuroSea project.

The final results of this step have been consolidated in milestone MS10, one publication on MHWs in the Copernicus Ocean Status Report 2020 (Dayan et al., 2022), another in Frontiers of Marine Sciences (Dayan et al., 2023) and are the core of deliverable D2.4.

We have also responded to the new EU Horizon2030 call and have been funded under the new ObsSea4Clim[25] project to continue and expand these efforts (the new project will start in February 2024).

Task 2.2: Observing System Design Experiments with global ocean monitoring systems

Task leader: MOI, Partners: MOI, CLS, ENS

Global OSSEs produced in the previous period with the Mercator Ocean physical global 1/4° ocean monitoring system were analysed to highlight how different in situ ocean observing networks are constraining the ocean circulation. More precisely, the analysis was focusing on how accurately climate indicators, such as heat and freshwater contents, are reconstructed depending on the assimilated sets of observations. The contribution of satellite observations, i.e. altimetry and SST, Argo and tropical mooring was considered and additional experiments were conducted to assess the potential impact of an increased resolution of the Argo network as planned for OneArgo[26] and increased vertical resolution of tropical moorings. The contribution of the assimilated observations to improve the temperature and salinity meso-scale and large-scale estimations in each of those experiments was also considered.

The Argo BGC observations are not assimilated in the real time BGC global monitoring and forecasting system. In the previous period, they were used to evaluate the PISCES global BGC model[27] uncertainties by comparison to the observed variance locally, when there was a sufficient number of observations to get a reliable estimate of the signal variance. A more sophisticated metric for the model efficiency compared to observation-based climatology was defined during the later period-based on model observation misfits. Bio-regions were also defined at global scale, with the identification of poorly observed regions that prevent the evaluation of the model errors.

Two papers on the work carried out during EuroSea were published: Mignot et al. 2023[28] and Gasparin et al. 2023[29].

[25] Horizon Europe project funded under the call "Closing the research gaps on Essential Ocean Variables (EOVs) in support of global assessments" / TOPIC ID: HORIZON-CL6-2023-CLIMATE-01-8

[26] https://argo.ucsd.edu/oneargo/

[27] https://www.pisces-community.org/

[28] https://doi.org/10.5194/bg-20-1405-2023

[29] https://doi.org/10.3389

Task 2.3: Observing System Simulation Experiments: impact of multi-platform observations for the validation of satellite observations

Task leader: CSIC, Partner: CLS, IMT, OceanNext, SOCIB

Following the design of the OSSEs published in deliverable D2.1, work on the following subtasks was conducted and completed during this reporting period. Final results are presented in detail in deliverable D2.3.

Subtask 2.3.1: Three different model outputs (CMEMS, WMOP, eNATL60) were used to simulate the observations from different multi-platform sampling strategies in the western Mediterranean Sea and North Atlantic. Applying statistical parameters, we evaluated the different sampling strategies and compared them with the "ocean truth" from the respective nature run models.

The different steps were conducted as follows:

- Extraction and sharing of model outputs: eNATL60, WMOP, CMEMS reanalysis (partners: Ocean Next, SOCIB and CSIC)
- Generating of configurations of the different sampling strategies in the Mediterranean and Atlantic regions (partner: CSIC)
- Simulating observations of CTD, underway CTD, ADCP and gliders (partner: CSIC)
- Reconstruction of simulated observations with the spatial optimal interpolation (partner: CSIC)
- Implementation of a new reconstruction method based on the spatio-temporal optimal interpolation (partner: CSIC)
- Reconstruction of simulated observations with the spatio-temporal optimal interpolation (partner: CSIC)
- Statistical evaluation of the best sampling strategies in each region and for each model (partner: CSIC)

One scientific paper from the work conducted in subtask 2.3.1 of EuroSea was published in the journal Frontiers in Marine Science: Barceló-Llull B. and Pascual A. (2023)[30]. In addition, the dataset and codes generated in this study were published at Zenodo[31,32]. These codes were shared on the SWOT Adopt-A-Crossover Consortium website[33] in preparation for the validation of the SWOT satellite mission. Also, they were continuously developed as part of a master's thesis that was defended in September 2023. In addition, they were adapted to plan the FaSt-SWOT experiments, conducted in April – May 2023 in the western Mediterranean Sea to validate the first observations from SWOT.

[30] https://doi.org/10.3389/fmars.2023.1082978

[31] Bàrbara Barceló-Llull, Ananda Pascual, Aurélie Albert, Jaime Hernández-Lasheras, Stephanie Leroux, & Baptiste Mourre. (2022). Dataset generated to evaluate in situ sampling strategies to reconstruct fine-scale ocean currents in the context of SWOT satellite mission (H2020 EuroSea project) (V1.0) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.6798018

[32] Bàrbara Barceló-Llull. (2023). Codes generated to evaluate in situ sampling strategies to reconstruct fine-scale ocean currents in the context of SWOT satellite mission (H2020 EuroSea project) (v1.0.0). Zenodo. https://doi.org/10.5281/zenodo.7543697

[33] https://www.swot-adac.org/resources/eurosea-osses-tool/

Subtask 2.3.2: Test different methods to reconstruct the simulated observations: spatial optimal interpolation, spatio-temporal optimal interpolation, WMOP data assimilation and machine learning techniques.

This included the following steps:

- Reconstruction of simulated observations with the spatial optimal interpolation (partner: CSIC)
- Evaluation of the spatial and temporal correlation scales (partner: CSIC)
- Development of a new method to reconstruct the observations based on an advanced version of the optimal interpolation which includes the temporal variable (partner: CSIC)
- Evaluation of the impact of including the temporal variable and correlation scale in the optimal interpolation (partner: CSIC)
- Reconstruction of simulated observations with the spatio-temporal optimal interpolation (partner: CSIC)
- Reconstruction with WMOP data assimilation (partner: SOCIB)
- Reconstruction with machine learning techniques (partner: IMT)
- Comparison of the reconstructed fields with the "ocean truth" (partners: CSIC, SOCIB, IMT)

Subtask 2.3.3: The aim of this subtask was to use surface drifters in addition to nadir altimetry to improve the accuracy and resolution of SLA maps, usually constructed only from nadir altimetry. We evaluated the performances of the reconstruction with the MIOST tool and analysed if this merging could be useful for the validation of SWOT. In this experiment we also evaluated the impact of tripling the number of drifters and quantified the impact in terms of resolution. This study was done in the Mediterranean and for the observations simulated from eNATL60.

This subtask included the following steps:

- Simulations of observations needed for this OSSE were done based on the eNATL60 numerical model: drifters, SWOT, nadir altimeters (partners: Ocean Next and CLS).
- First test of reconstruction with MIOST raised an issue concerning the dynamical atmospheric impact on Sea Level Anomalies (SLA) within eNATL60. This signal has a large spatial scale and high temporal frequency. The temporal frequency of this signal is too high regarding the altimetric coverage and repetitively: it was thus impossible to reconstruct with our method. We needed to remove this signal in the simulated SLA (note that when dealing with real observations of SLA, this signal is removed and called: Dynamical Atmospheric Correction (DAC)). We successfully solved this issue. (partners: Ocean Next, CLS and SOCIB)
- Reconstruction with the MIOST tool to map nadir altimetry using drifters (partner: CLS)
- Analysis of the results presented in D2.3 (partner: CLS)

Cooperation and interaction with other EuroSea WPs

Co-operator	WP activities
WPs 4, 5, 6 and 7	• Co-development and consolidation of EuroSea indicators
WPs 4, 5, 6 and 7	• Development of MHWs metrics and indicator requirements in terms of EOVs/ECVs
WP3	• Discussion about synergies between T3.9 and T2.3

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
SWOT Science Team	• Participation in the regular meetings organised by the SWOT Science Team Regional Validation and High-resolution ocean modelling working groups.
SWOT Adopt-A-Crossover Consortium	• The codes developed in subtask 2.3.1 were shared on the SWOT Adopt-A-Crossover Consortium website as a tool to prepare the validation of SWOT.
FaSt-SWOT project	• The recommendations and codes from subtask 2.3.1 were used to plan the FaSt-SWOT experiments.
Ocean Observing Co-Design UN Ocean Decade programme	• Co-development of indicators, metrics for EOVs/ECVs and development of a process for the recurring evaluation of the observing systems design
OceanPredict / ForSea UN Ocean Decade programme	• Development of procedures and metrics for EOVs/ECVs and development of a process for the recurring evaluation of the observing systems design

Achieved main results

Deliverables		
D2.3	Analysis of the OSSEs with multi-platform in situ data and impact on fine-scale structures	✓
D2.4	Development of targeted indicators and their uncertainties for demonstrators and Forecasts	✓
Milestones		
MS10	Requirements of EOVs and platforms for sustaining indicators for WP4-7	✓
MS11	User driven indicators defined and selected EOV/ECV from ensemble of seasonal forecasts verified	✓

WP3 - Network Integration and Improvement

Lead: HCMR, CO-lead: GEOMAR

Objectives
• Oversee key aspects of integration of European observing technology for its optimal use in an EOOS and global initiatives (e.g. GOOS) and, in parallel, addressing national interests. The integration has two dimensions: observing networks, grouped around technology or platforms (mooring, tide gauges, glider, floats, ships, etc.), and thematic networks, grouped around a certain observing challenge (e.g. metagenomics, data, scientific issues).
• Ensure that most observing networks reach TRL7, defined as: ○ Network coordinates a community of Best Practice around a specific technology ○ Network specification and governance structure is articulated (e.g. Terms of Reference) ○ Network data policy is defined and comply with FAIR principles (findable, accessible, interoperable, re-usable) ○ Long term (>10 years) sustained observing needs are defined ○ Networks are open to all operators of the respective observing technology ○ Best Practices for each network, addressing the EOV specification sheets, are documented and deposited at oceanbestpractices.org
• Improve internal coordination within the observing networks, guided by scientific/engineering expertise and supported by a technical coordinator
• Interact with the observing component in the EuroSea Demonstration activities (WP5,6,7)
• Proof Best Practice documentation
• Enable a dialogue between observing requirements and the underlying scientific approach and the technology framework that is coordinated by the observing networks
• Ensure data delivery according to standards including communication pathways between platform operators, observing networks and data centres.

Summary of progress towards WP objectives

During the final project phase, WP3 tasks have been particularly active towards objectives. In total 13 deliverables were finalised and submitted, as well as 1 milestone and 7 internal milestones.

Between May 2022 and October 2022, the Argo network adopted new Terms of Reference for the EuroGOOS task team which becomes more inclusive targeting non EuroArgo ERIC partners. Underwater gliders have been particularly active, progressing on the OceanGliders GitHub community and the OceanGliders Best practices efforts in cooperation with WP1 and the OBPS steering group. An overview paper and 6 standard operating procedures were prepared. Moreover, a European Glider Data management workshop was organized in July 2022 in collaboration with the EuroGOOS glider Task Team and the H2020 GROOM II project during which all data related issues were discussed and a roadmap for the future defined. Parallel to these, several activities and meetings took place in the framework of collaboration with the Ocean Gliders OCG the EuroGOOS gliders task team and GROOM II project. Vessels held their 2nd European FerryBox workshop in Geesthacht, Germany (27-28 September 2022) organized in collaboration with EuroGOOS and JERICO-S3 with a wide participation from countries outside the EuroGOOS TT. Acknowledging the importance of OceanOPS, a webinar was organized on metadata submission. Improving the connection with OceanOPS has also been central for the Eulerian Observatories with a respective deliverable (D3.12) being submitted. In this report discrepancies and overlaps in today's system were identified while recommendations are made following a

detailed analysis of the landscape. Towards improving sea level data interoperability and strengthening coordination between European sea level operators and global programs, the Sea Level Network during this period made available 1) the Tide Gauge Metadata Catalogue for the European sea level network, 2) a preliminary version of a data portal based on sea levels measured by the GNSS-IR technique, and 3) the tool for intercomparing between different data portals integrating tide gauge data. The HF-Radar network shared with other networks the report on the governance (deliverable D3.4) which can act as template. Parallel to this, new tools were developed for improving processing capacities and generating semi-automatic reporting outputs which integrate the interaction between the Node and the local operators responsible for the Data Quality of their systems. Taking the first steps as a network in the framework of EuroSea, the Autonomous Surface Vehicles (ASVs) during this period focused on the organization of an international workshop on ASV technologies bringing together members of the industrial sector, academia and agencies. In addition, dissemination actions targeted towards the engagement with leading actors. Augmented Observatories work focused on the creation of Metagenomic Assembled Genomes (MAGs), a database of the DNA of the most ecologically relevant species. This database will permit identifying the genes allowing for the species thriving in the coastal ecosystem and, via the mapping of the metrascriptomes, to identify the metabolic states of the species during the different environmental conditions experienced along the seasonal cycle (e.g., eutrophication vs oligotrophy). During this period task 3.9 (Integrating Science) presented the work done (Rèvelard et al., 2022) in meetings and published media. In the framework of task (3.10 Interface with In Situ data integrators), a Data Management Plan (D3.1) was issued by the EuroSea partners. Furthermore, an important task started during this period to propose some metadata and to review with WP3 task leaders what was existing or not in their networks that later on led to the deliverable D3.7 (Network harmonisation recommendations).

Between November 2022 and October 2023, the WP3 worked towards the finalisation of task activities and the preparation for the final meeting and the EuroSea symposium. In parallel to this, the partners worked on the final assessment of all observing networks with the delivery of the respective report (D3.18). In terms of the individual task efforts, all tasks participated in the WP3 hybrid meeting on 15-16 March 2023. In summary, the Argo network worked on the update of Euro-Argo Deep and BGC strategy (D3.16) with the report being submitted in August 2023. Underwaters Gliders activities were concentrated in the organization of the upcoming 9th EGO conference[34] in summer 2024. Taking benefit of the Eurofleets+[35] project 2022 General Assembly, the Vessels network organized a workshop during which synergies between EU projects were exploited on key issues such as unique lifecycle identifiers, machine to machine exchange of cruise plans, and (meta-)data flow. Eulerian Observations network delivered the report on Best Practices, an important document which looks into many different aspects of fixed observatories as well as on issues such as best practice guidelines for variables measured by different fixed platforms. Moreover, a registry with the 205 fixed platforms operating in the 13 Member States was accomplished which in the framework of AMRIT[36] project will be incorporated in the OceanOPS. The Sea Level network organized its second hybrid workshop in May 2023 with a broad participation from the international community. The Tide Gauge Metadata Catalogue (EUTGN[37]) tool produced in the previous period was added to the EuroGOOS Tide Gauge Task Team website (deliverable D3.15). Furthermore, the Permanent Service for Mean Sea Level (PSMSL, NOC)

[34] https://voiceoftheocean.org/save-the-date-international-underwater-glider-conference-2024/
[35] https://www.eurofleets.eu/
[36] https://www.deutsche-meeresforschung.de/en/projekt/amrit/
[37] http://eutgn.marine.ie

data portal for sea level from GNSS-IR[38] was released to a live environment while a web version of SONEL[39] was developed and released in early 2023 for the intercomparison of the data and metadata portals, helping the identification of gaps and errors. The HF Radar network reported on the different tools developed in the framework of the EuroSea project (D3.14) all of which are a direct respond to identified requirements by the community. For the dissemination of all those new capabilities a website[40] has been created offering a wide visibility to the network. The second workshop of the ASVs with the participation of numerous international partners focused on the regulatory framework and the definition of a roadmap for the implementation of the ASV Network and its future sustainability, beyond EuroSea. The Augmented Observatories network has almost completed the first set of Metagenomic Assembled Genomes (MAGs) which will be released to international public repositories. Task 3.9 reported an example of ocean integration through the FaSt-SWOT multi-platform experiment in the Balearic Sea, while building on the previous work on "Ocean Integration", a vision for a real implementation of EOOS has been proposed. Finally, in the scope of task 3.10 a "data handbook" has been delivered (D3.13) with very useful information on each of the EuroSea networks as well as a report on "Data Integration" (D3.17) which looks into the links with the European in situ data integrators exploring similarities and gaps.

Detailed progress per task (or subtasks)

Task 3.0: Coordination

In the framework of coordination activities, WP3 organised an online meeting with the task leaders during which each task presented the activities foreseen in the DoA and those completed, the problems encountered and what mitigation actions were taken, as well as the activities scheduled for the remaining time of the project. Particular attention was paid to the delays. In June 2023, WP3 organised an in-person meeting in Brussels. During the first part of the meeting the tasks presented their progress and the main results achieved. Following, there was a discussion on recommendations for future integration across Europe considering EuroGOOS, EOOS, and infrastructure-like activities, as well as with global initiatives such as GOOS and the Observations Coordinating Group (OCGs). The next day was devoted to the discussion on some cross-cutting issues on data/metadata ingestion in European and global data/metadata integrators (led by task 3.10).

Task 3.1: Argo

Task leader: Euro-Argo Eric, Partners: Ifremer, SU

Time period: 1 May 2022 – 31 October 2022

Following a change of scope of the Argo EuroGOOS Task Team late 2021, new Terms of Reference for the Task Team were prepared and submitted to the EuroGOOS governance in spring 2022. These new Terms of Reference were endorsed by EuroGOOS late 2022. The change of scope includes better articulation between the Task Team and the Euro-Argo Management Board, and emphasis on the role of the Task Team in facilitating the collaboration between Euro-Argo and its potential new members. The new Task Team is co-led by representatives of Portugal and Belgium, two countries that are not part of the Euro-Argo ERIC at the moment.

[38] https://psmsl.org/data/gnssir/index.php
[39] https://www.sonel.org/tgcat/
[40] https://www.hfrnode.eu/

Euro-Argo ERIC organised the 7th Argo Science Workshop in Brussels, on 11-13 October 2022, where discussions on scientific aspects of the Deep and BGC Argo components that started during the 2021 Deep and BGC Argo workshop[41] were continued in an international context.

In 2023, an ad hoc Working Group (WG) was set-up by Euro-Argo ERIC to work on the update of Euro-Argo Deep and BGC strategy. A meeting was organised among the WG in April 2023 (Euro-Argo ERIC, IFremer, SU) to set the outline and global content of this new strategy (D3.16). The writing of the document by the WG occurred in spring and summer 2023 with a final submission of D3.16 in August. Inputs were also provided for the last WP3 meeting in June 2023, to prepare Argo contribution to D3.18, and efforts were provided in July for the final version of D3.18.

In July 2023, Euro-Argo participated virtually in the 2nd EuroSea / OceanPredict workshop[42]. Euro-Argo ERIC also spent some time preparing the EuroSea final meeting in September 2023, in particular contributing to the observing networks exhibition, in collaboration with CNRS (gliders).

Task 3.2: Underwater Gliders

Task leader: CNRS, Partners: WMO

Task 3.2 continued to animate the OceanGliders GitHub community and the OceanGliders Best practices efforts. GitHub is a new tool to foster global collaboration in an effective, inclusive, open, transparent and asynchronous way. It provides community tools like issues, approval mechanisms and document governance. It allows people to engage in their time zone, their schedule and pace.

These best practices efforts were coordinated and co-designed with WP1 Best Practices and the steering group of the Ocean Best Practice System (SG-OBPS). Interactions with task 1.1 “Observing and forecasting system coordination, national, regional, global” and more particularly with subtask 1.1.4 “Ocean Best Practices”.

The task team made progress on glider data management. They have been actively engaged in organizing a European Glider Data management workshop in collaboration with EuroGOOS glider Task Team and H2020 GROOM II[43] in July 2022. The meeting was held on two weeks. The first week of the meeting aimed at discussing short term data management issues while the second week of the meeting aimed at discussing the longer-term data management issues. The larger community of glider data “stakeholders” was invited to join three sessions focusing on:

- The data management architecture of DACs (Data Assembly Centers) and GDACs (Global Data Assembly Centers) in Europe and the role of NODCs (National Ocean data Centers) in this regard,
- The future needs in terms of data management regarding the increasing capacity of glider to measure new type of data (sound, images, samples, …),
- The GROOM RI data management road map.

Task 3.2 has organized the OceanGliders Steering Team meetings (December 2020, December 2021, June 2022), a call for new Task Teams and a call for nomination to renew the Steering Team in January 2022.

[41] https://www.euro-argo.eu/News-Meetings/Meetings/Others/BGC-Deep-Argo-Workshop
[42] https://oceanpredict.org/archived-events/eurosea-oceanpredict-workshop-2/#section-eurosea-overview
[43] https://www.groom-ri.eu/

The task team continued to collaborate with the other WP3 tasks. A presentation entitled "Recommendations on data harmonization for ocean observation networks" (Obaton et al, 2022 proceeding in IEEE) was given at MetroSea 2022[44]. In addition, the task contributed to the WP3 publication Révelard et al. (2022). Furthermore, Best Practices were developed in collaboration with BGC ARGO experts and a broader community was convinced that GitHub is a good approach to develop such documentation on BP.

Task 3.2 also collaborated with task 4.1 "Assimilation in the global and North East Atlantic (IBI) Copernicus Marine modelling system and analysis/forecast quality assessment" and task 4.2 "Assimilation in the Mediterranean Sea Copernicus Marine modelling system and analysis/forecast quality assessment" on the assessment of the impact of glider observations on the ocean analysis/forecast products. Achievements were presented at the EuroSea/OceanPredict Workshop on Ocean Prediction and Observing (June 2022) and at the UG2 Workshop Seattle '22 (USA, Seattle, September 2022) and a dedicated repository was set up on the OceanGliders Github page.

Strong linkages between EuroGOOS GTT, GROOM II and EuroSea task 3.2 due to shared coordination (EuroGOOS GTT chaired by Carlos Barrera, Pierre Testor and Victor Turpin; H2020 GROOM II coordinated by Laurent Mortier and Pierre Testor; EuroSea WP3 task 3.2 led by Pierre Testor) supported the alignment of efforts with many video conferences during the project with the different stakeholders. The EuroSea project resources helped both European and international communities to move forward in terms of integration and coordination, as well as to develop a solid basis for the development of Best Practices in an international context. These are all important aspects that would have to be handled by the future GROOM-RI that is being designed by H2020 GROOM II with respect to the integration of the European glider activity in the future EOOS.

Finally, task 3.2 has worked on a report on European glider network coordination (D3.9) which provides details on what has been achieved during EuroSea in this task. The report covers best practices, OceanGliders, metadata, and data management. The work on OceanGliders Best Practices overview paper and 6 Standard Operating Procedures was continued.

Most recent activities focussed on the work on the logistical, financial and scientific aspects in the organisation of the 9th EGO meeting (International Underwater Glider Conference), a major event for the international glider community that will be held in Sweden Gothenburg 10-14 June 2024. At the EuroSea Symposium the task 3.2 partners displayed a fake glider and a fake profiling float (scale 1:1) as demonstrators for observing systems in the hall of the conference.

Task 3.3: Vessels

Task leader: NIVA, Partners: WMO

Task 3.3 partners held a second European FerryBox workshop in Geesthacht, Germany from 27-28 September 2022 which was organised by EuroSea, JERICO-S3, EuroGOOS, and sponsorship from marine sensor and FerryBox-related SMEs. It consisted of two days with 40+ oral presentations in six sessions, ~50 in-person participants and ~25 virtual participants (including discussions related to best practices, linking the task activities to other regional/global efforts like ICOS-ERIC[45], SOCAT[46], cost efficiency/assessments related to

[44] https://www.metrosea.org/ms2022/
[45] https://www.icos-cp.eu/about/organisation-governance/icos-eric
[46] https://socat.info/

operations, data management, and novel/developing sensor and sampler technologies). The workshop also included participation of scientists from Bulgaria, Cyprus, Tunisia, Chile, and Brazil - countries underrepresented and not yet involved in the EuroGOOS Task Team. The partners also hosted a webinar on 12 September 2022 to provide training for users on how and where to submit metadata in the new metadata formats to OceanOPS. Task partners also took part in a common WP1-WP3 workshop on Best Practices and a stakeholder workshop with WP8.

In November 2022 the partners held a Research Vessel workshop at the EU Eurofleets+ project 2022 General Assembly in Barcelona, Spain as a forum to exploit synergies between EU projects and to address unique lifecycle identifiers for cruises, machine to machine exchange of cruise plans, and issues with (meta-)data flow from underway systems installed in research vessels. The partners also participated in the EuroSea foresight workshop held in Brussels on 15-16 March 2023 and provided insight on behalf of the task (vessels and ships of opportunity) in terms of network development and future operational capacity and coverage of EOVs. The task team also participated and presented EuroSea's vessels task and network at the WMO/UNESCO Ship Observations Team 12th session (Melbourne, Australia) on 16-18 May 2023. Finally, task partners contributed to the GOOS Co-design workshop on 20 September 2023 in Paris, France that was held in conjunction with the EuroSea General Assembly.

Task 3.4: Eulerian Observations

Task leader: SU, Partners: EMSO-Eric, WMO

The deliverable D3.12 was submitted on October 31, 2022. Its purpose was to create a metadata catalogue for fixed-point observations for the OceanOPS portal[47] (WMO). This endeavour helped identify challenges and foster better connectivity among community members. The metadata format and exchange system need enhancement to facilitate the transmission and display of information related to fixed platform deployments. The significant challenge faced was the lack of priority in metadata submission by platform operators to a central node such as OceanOPS. It was observed that different catalogues of Eulerian ocean observation systems, though overlapping, contain discrepancies. This issue can only be resolved by improving cooperation among key stakeholders, including primary site operators, European data aggregators, EMSO ERIC, OceanSITES, DBCP program, national and regional Eulerian networks, and OceanOPS. The EuroGOOS Fixed Platform Task Team (EuroGOOS FP TT) has been designated as the forum for raising and discussing these monitoring issues among the previously identified stakeholders. In doing so, the task team could establish a more efficient communication hub for various stakeholders regarding metadata sharing and a more comprehensive examination of machine-to-machine metadata interoperability and exchange.

In December 2022 the deliverable D3.11 on Best Practices has been produced. The variables discussed in this deliverable span various domains, ranging from physics to geophysics, for water column and seabed observations conducted by Eulerian platforms. Most of these recommendations highlight the fact that variables measured automatically at high frequencies cannot do without in-situ measurements, which necessitate the presence of research vessels, impacting the finances and environment of the nations and programs responsible for these platforms. Undoubtedly, other alternatives should be considered, such as the use of surface drones or the application of neural networks to estimate data accuracy and enable data correction. However, this would require a broader community discussion. It is also conceivable that advancements in marine technologies (e.g. microfluidic systems, chips) capable of collecting and analysing

[47] https://www.ocean-ops.org/board

seawater will offer better opportunities to constrain and estimate the performance of autonomous sensors deployed on moorings. Ultimately, the objective of this report was to propose best practice guidelines for variables measured by different fixed platforms. It served as a synthesis of recommendations related to the measurement of various variables, the maintenance of associated sensors, and current data correction procedures. To form a comprehensive best practice guide, the suggestions outlined in this deliverable must be endorsed by a broad community using fixed platforms for observations to achieve a general consensus.

During the EuroGOOS conference in Galway in 2023, the Fixed Platform Task Team (FP TT) accomplished the task of creating a map of currently operating fixed platforms, with the overarching objective of keeping an updated inventory (Gurdebeke et al., 2023). They successfully identified a total of 205 fixed platforms in 13 European countries. This data encompassed crucial details such as the operating institution, station name, WMO code, geographic coordinates (latitude and longitude), depth, and platform type. This valuable information was subsequently shared with OceanOPS to assist them in consolidating information about active fixed platforms in Europe, as documented in D3.12. For the future, FP TT's role will be crucial in keeping the FP community structured, with a strong link to OceanOPS to promote European FP activities.

Task 3.5: European Sea Level Network

Task leader: EPPE, Partners: NOC, CNRS, MI

During the previous period the first versions of the main developments of EuroSea task 3.5 were made available, including the Tide Gauge Metadata Catalogue for the European sea level network, a preliminary version of a data portal based on sea levels measured by the GNSS-IR technique, and the tool for intercomparison between different data portals integrating tide gauge data. Some of these developments come from the recommendations provided in the “New tide gauge data flow strategy” (deliverable D3.3)[48], for improving sea level data interoperability and strengthening coordination between European sea level operators and global programs such as the Global Sea Level Observing System or Copernicus.

During this reporting period the European Sea Level Network has progressed on the following actions, related to the proposal milestones and deliverables for this task: 1) The 2nd EuroSea Tide Gauge Network workshop was a hybrid event held at EPPE, Madrid and virtually on 4th and 5th of May 2023. Like the first workshop, this event aimed to bring together the global tide gauge community to share experiences, exchange information on recent activities and discuss ways to overcome the challenges across different geographical regions, but also had a greater focus upon data processing and quality control of observations. The following topics were covered: Status and future possibilities of Global Navigation Satellite System Interferometric Reflectometry (GNSS-IR), global overview of networks, datasets and data portals, automatic quality control and data processing (real time and delayed mode) and case studies based on tide gauge data. The minutes and the corresponding internal milestone iMS41 were submitted on time in June 2023. 2) In November 2022 a link to the centralised Tide Gauge Metadata Catalogue (EUTGN[49]) tool was added to the EuroGOOS Tide Gauge Task Team website[50], ready to be populated by tide gauge operators and members of the Task Team. It included instructions on how to edit and complete the fields. The tool can also be accessed by data portals and data aggregators to standardise metadata records. The corresponding deliverable D3.15 (Tide Gauge Metadata Catalogue) was produced and delivered in May 2023. Developed by the Irish Marine Institute, the

[48] https://doi.org/10.3289/eurosea_d3.3
[49] http://eutgn.marine.ie
[50] https://eurogoos.eu/tide-gauge-task-team/

catalogue includes position and basic metadata of permanent sea level monitoring nodes for European and adjacent coastlines, including North Africa. This deliverable was prepared after consultation with EuroSea partners and EuroGOOS Tide Gauge task team members. 3) The Permanent Service for Mean Sea Level (PSMSL, NOC) data portal for sea level from GNSS-IR[51] was released to a live environment and comprises over 400 additional sea level records from existing GNSS networks. The data portal includes comprehensive metadata, documentation and information about the technique, as well as tools to help in the establishment of new GNSS-IR sites. This data portal was developed as part of deliverable D3.3. 4) SONEL (CNRS) has continued to explore the status of existing data portals with tide gauge data. For that, it has developed an automatic code to compare the contents for the main data portals in terms of gaps and duplicates. In order to make this tool available for the Tide Gauge community a web version[52] was developed and released in early 2023. This online tool allows the user to intercompare the content of the main data or metadata portals, which will help to identify gaps in portals or to find geographical coordinates errors and should help to unify the station names. These tools should be useful in the process of unifying the portals in terms of metadata and go towards a new unique ID, as indicated in deliverable D3.3.

On February 8, 2023, these products developed for the European sea level network in the frame of EuroSea were presented at the IX EuroGOOS Tide Gauge Task Team Annual Meeting. In addition, these achievements were also presented at the 28th IUGG General Assembly in Berlin (11-20): G06p-127: Priorities for Monitoring Sea Level with Tide Gauges in Europe.

Task 3.6: HF Radar

Task leader: AZTI, Partners: CNR, SOCIB, EPPE

The deliverable D3.4 (HF-Radar Governance) a proposal for improving the governance of the European HF Radar network, which was submitted in the previous reporting period, has been discussed with the other networks as a contribution in the EuroSea internal workshop on Observing Network Governance during the EuroSea Annual Meeting 2022 in May 2022. In order to support the improvement of centralised Near Real Time and delayed-mode products coordinated by the European HFR Node, new tools have been developed for improving processing capacities and generating semi-automatic reporting outputs which integrate the interaction between the Node and the local operators responsible for the Data Quality of their systems. For improving the capacities of the European HFR Node, the development of HFR Online Outage Reporting Tool [HOORT] has been started with the support of MARACOOS[53] (Mid-Atlantic Region US). The deliverable D3.14 (HF-Radar Tools) provided a description of the different tools developed for tackling key issues of the High Frequency Radar (HFR) community: advanced delayed time QC of HFR historical data, implementation of Best Practices, enhancing the application of HFR observations in NRT modelling assessment and Ocean State indicators. In particular, a significant step has been obtained with the HOORT tool, a web-based application for HFR operators to aid HFR operations and maintenance and keep operators more aware of common problems, helping them to detect the most common cause of outages and to report them. The main objectives are threefold (DAR: Detect-Alert-Report): 1) automatically detect the outage, 2) automatically alert the HFR operator, and 3) provide an interface to manually report the outage and therefore collect a meaningful statistic of common operational issues.

[51] https://psmsl.org/data/gnssir/index.php
[52] https://www.sonel.org/tgcat/
[53] https://maracoos.org/

Moreover, the work on the High-frequency radar-derived coastal upwelling index has been published by Lorente et al. in the 7th edition of the Copernicus Ocean State Report[54].

An annual HFR Radar Task Team workshop was carried out in November 2022. It helped to exchange information on recent activities, share experiences, and discuss ways to forward the future. 27 people from 6 countries attended the High Frequency Radar (HFR) workshop on a hybrid on-site/online format. 5 main topics were tackled during the workshop: 1) JERICO Coastal Ocean Resource Environment (CORE) as a platform to support HFR activities, 2) HOORT [HFR Online Outage Reporting Tool: What is it and how does it work, 3) The European HFR Node: Quality Control on surface current data, 4) DOI strategy. DOI of systems vs. DOIs of data, and 5) Waves from HFR.

Efforts on communication have been continued with a new EuroGOOS HFR community newsletters "Taking the pulse of the coastal ocean" in Aug 2022 and October 2023.

Finally, a first attempt of a website[55] has been created in order to share all the community tools developed during EuroSea project and give more visibility to the HF Radar data providers following the established DOI strategy.

Task 3.7: Autonomous Surface Vehicles

Task leader: PLOCAN, Partners: UBREMEN, UPORTO, NOC

The first workshop on ASV technologies organized within the framework of task 3.7 brought together for the first time at an international level a wide representation of the main developers and users, which made members of the industrial sector, academia and agencies aware of the initiative making known both the state of the art and main applications and needs in terms of regulation for the operation of ASV on a routine basis in the different tides and ocean basins of Europe.

With the main goal to engage leading actors representing developers, industry, academia, end-users and regulatory bodies to provide an overview on current trends in USV technology, while seeking a baseline understanding of the sector from lessons learned at technical, operational, data management and policy/regulatory levels, dissemination activities related to task 3.7 have been conducted in this period through the following international and national forums and events: iXBlue Seminar on ASV (May 2022 - online), Autonomous Ship Expo (June 2022 – online), MTI Marine Robotics Summer School (July 2022 - online), International Symposium on Marine Sciences 2022 (July 2022 – Gran Canaria), IMO Seminar on Development of a Regulatory Framework for Maritime Autonomous Surface Ships -MASS (September 2022 – online), Jornada Tecnica sobre Buques Autonomos DGMM (October 2022 - Madrid), Glider School 2022 (October 2022 – Gran Canaria). We have also collaborated in deliverable D3.7 "Network harmonization recommendations", mainly Christoph Waldmann (MARUM), contributing with the information requested to compose the metadata relevant to the ASVs.

Based on the knowledge derived from the first workshop, a second workshop enabled a much more specific content agenda by the attending experts, among whom were NOAA representatives associated with the OASIS program. Among the topics discussed, we highlight the regulatory framework and the definition of a

[54] https://doi.org/10.5194/sp-1-osr7-8-2023
[55] https://www.hfrnode.eu/

roadmap for the implementation of the ASV Network and its future sustainability, beyond the EuroSea period.

The synergistic links between EuroSea and the OASIS program (endorsed by UN Ocean Decade) have allowed specific collaborative actions to be carried out, among which the participation of NOAA personnel in the 2nd EuroSea ASV workshop and that of PLOCAN in the OASIS Workshop Series stand out. In turn, this collaborative framework enabled the proposal and inclusion in the scientific-technical program of the Ocean Sciences Meeting 2024 a specific session on ASV technologies and their applications.

As part of its legacy, task 3.7 has enabled to identify and promote national working groups on ASV technologies, as is the case of Spain, which is included within the National Working Group on Autonomous Ships, led by the General Directorate of the Merchant Navy. EuroSea partner PLOCAN is a member of this group.

With the same main goal, for this period several dissemination and engagement actions have been conducted with regards to task 3.7 at the main leading events and forums such as MATS 2022 (November 2022 – Southampton), AINE 2022 (November 2022 – Madrid), 8th UK MASS Conference (January 2023 - online), iXblue Conference (January 2023, Edinburg), Oceanology Americas 2023 (February 2023 – San Diego), OASIS Webinar Series (March 2023 – online), MCDEE 2023 Conference (April 2023 – London), Ocean Business 2023 (April 2023, Southampton), OASIS Webinar Series (April 2023 – online), 2nd EuroSea USV Workshop (May 2023 – Gran Canaria), Oceans 2023 IEEE/MTS (June 2023 – Limerick), MARTECH 2023 (June 2023 -online), Autonomous Ships Conference (June 2023, Amsterdam), MIT Summer School (July 2023, online), Oceans 2023 IEEE/MTS (September 2023, Biloxi), EuroGOOS Conference 2023 (October 2023, Galway), Glider School 2023 (October 2023, Gran Canaria).

In summary, the initiative to define and implement a new European observing network based on ASV technologies has allowed the main members of the industry, academia and regulatory/governmental field to be aligned under the same goal, in order to identify and generate synergies and added value at science, services and business level beyond EuroSea period.

Task 3.8: Augmented Observatories

Task leader: SZN, Partner: AWI

The sequencing of the first samples has been finally completed. The resulting metabarcoding, metagenomic and metatranscriptomic data covers a period going from April 2019 to February 2020. The size of the raw data set amounts to 1 Tb. The -omics dataset covers organisms from bacteria to small metazoan such as copepods, fish larvae and pelagic tunicates. A postdoc with a background in molecular biology was charged of the bioinformatic analyses. After the assembly, the further processing followed three different strategies: 1) the production of a taxonomic dataset based on the 18s metabarcoding via taxonomic assignations by matching with reference databases; 2) the creation of a set of Unigenes, that is, of putative functional genes, when possible, having also functional and taxonomic assignations; 3) the creation of Metagenomic Assembled Genomes (MAGs), that is, of genomes derived directly from the in situ metagenomic data. The aim of the latter exercise is to create a database of the DNA of the most ecologically relevant species, database that will permit identifying the genes allowing for the species thriving in the coastal ecosystem and, via the mapping of the metatranscriptomes, to identify the metabolic states of the species during the different environmental conditions experienced along the seasonal cycle (e.g., eutrophication vs oligotrophy). The challenges associated with bioinformatic analyses are indeed complex. The postdoc has

thus spent a period of formation and preliminary analyses at Genoscope (Ivry, France), the partner of the observatory that is in charge of the sequencing and that collaborates on the scientific analyses. The focus has been on the activities (1) and (3). Colleagues at SZN have processed and prepared the data for the physical, chemical and biological parameters (e.g., microscopy counts of the species abundances).

The preparation of a first set of MAGs is now nearly completed. The MAGs cover different organisms, from bacteria to metazoan. In the case of the eukaryotes, 52 MAGs were reconstructed including, among others, the genomes of several diatoms (including a toxic one, a Pseudo-Nitzschia). The genomes coverage varies from 20% to 80%. Once completed the taxonomic assignation and the genes functional assignations the partners will release the MAGs on international public repositories, together with submitting a data paper that describes the pipelines and the data.

Meanwhile, in order to fully exploit the potential of the Augmented observatory and thus to have a holistic view of the ecosystem, the -omics data are being integrated with physical, biological and chemical data. In addition, the MAGs taxonomic assignation is allowing for combining this genomic information with the observation of the same species over the 30 years of the LTER site that is augmented by the NEREA[56] activities. The exercise serves as the basis for a deep understanding of the species ecology and biology and, thus, for the creation of innovative tools for the forecasting of its response to climate changes.

In terms of dissemination activities, partners involved in task 3.8 have been invited to present the Augmented Observatory NEREA, partially funded by EuroSea, to the Science meeting in preparation for the activities at sea of the new international program BioGeoSCAPES[57]. The science meeting will be held in Woods Hole (US) early in November 2023.

Task 3.9: Integrating science

Task leader: SOCIB, Partners: CSIC, AZTI

The work published by Rèvelard et al. in January 2022 has been presented in different conferences, e.g. ILICO General Assembly, Villefranche sur mer in November 2022. In addition, a report was written for milestone MS30 to demonstrate an example of ocean integration through the FaSt-SWOT multi-platform experiments conducted in April and May 2023 in the Balearic Sea (western Mediterranean). It was submitted in August 2023. Based on the publication entitled “Ocean Integration: the needs and challenges of effective coordination within the ocean observing system”, already reported in the previous period, in deliverable D3.8 (published in March 2023) a vision for a real implementation of EOOS has been proposed, by identifying the issues and barriers, also providing up to ten recommendations that could lay the foundation of and stimulate a real transformational change.

It also includes some examples of multidisciplinary integration as:

- Integration of HFRs with multiplatform and multidisciplinary data to study the influence of coastal circulation on the distribution of European anchovies.
- An integrated method for model skill assessment in the context of Search and Rescue combining multiple numerical models and data from HFR and drifters.
- Creation of an integrated dashboard for the Bay of Biscay (i.e. ebegi dashboard)

[56] https://www.nerea-observatory.org/
[57] https://biogeoscapes.org/

This work has been presented Ocean Sciences Board in May 2023 and the GOOS Steering Committee Meeting in Halifax in April 2023.

Task 3.10: Interface with In Situ data integrators

Task leader: IFREMER, Partners: ETT, OGS

The goal of task 3.10 is to connect the WP3 networks with the existing in situ data integrators that are CMEMS, EMODnet-Physics and Chemistry and SeaDataNet. To facilitate this integration a Data Management Plan (deliverable D3.1) was issued by the EuroSea partners early during the EuroSea project. The harmonisation of the work flow between the observing networks and the integrators through interoperable interfaces is based on existing international standards following up on the recommendations issued within the AtlantOS project and reported on several international scientific papers. It is associated with relevant metadata to form a possible common basis for the different networks involved in EuroSea. Then an important task started during this period to propose some metadata and to review with WP3 task leaders what was existing or not in their networks that led to the deliverable D3.7 (Network harmonisation recommendations).

The task 3.10 partners worked jointly with the task 3.9 partners contributing to the "Strategic European Vision of Ocean Integration" for the data management and delivery aspects and to the publication of Rèvelard et al. 2022.

During the final project phase, 2 additional deliverables were written: The first one, D3.13 "data handbook" provides an overview of each network of the EuroSea project including a short history, the measurements made, the data flow and the quality control proposed. In addition, a table shows the international networks with some data management characteristics and its European counterparts. This document was written with the support of each network involved in the EuroSea project. The second deliverable, D3.17 "Data integration" describes the 3 main in situ data integrators in Europe: Copernicus, EMODnet and SeaDataNet. It highlights the links between them with a comparison of what they propose to users. A metadata analysis by networks involved in EuroSea completed by what is done in each of these European data integrators show the similarities and the gaps between the 2 categories to be enhanced and homogenised to facilitate integration of the data to the integrators. Then 2 examples or use cases are described. They detail how users access the data they want depending on their needs considering each of the 3 European data integrators.

Cooperation and interaction with other EuroSea WPs

Co-operator	WP activities
WP1/T1.1.4 Best Practices	• Task 3.2 Underwater Gliders: co-design of best practices
WP4/T4.1	• Assimilation in the global and North East Atlantic (IBI) Copernicus Marine modelling system and analysis/forecast quality assessment
WP4/T4.2	• Assimilation in the Mediterranean Sea Copernicus Marine modelling system and analysis/forecast quality assessment

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
EuroArgo ERIC	• 7th Argo Science Workshop. October 2022, Brussels

GROOM II/EuroGOOS Gliders TT	• European Glider Data management workshop. July 2022, On line
MetroSea 2022	• Recommendations on data harmonization for ocean observation networks. October 2022, Milano
Underwater Glider User Group	• UG2 Workshop. September 2022, Seattle
EuroFleets+	• Research Vessel workshop at Eurofleets+ General Assembly. November 2022, Barcelona
Gliders School	• Gran Canaria, October 2022
WMO/UNESCO	• Ship Observations Team 12th session. May 2023, Melbourne
GOOS	• Co-design workshop. September 2023, Paris • Presentation at the GOOS SC meeting "The needs for enhanced ocean integration for enhanced global ocean observing". April 2023, Halifax
EuroGOOS	• Task Teams presentation during the annual General Assembly. May 2023, Brussels
OASIS program	• Participation in the 2nd ASV workshop. April 2023, Gran Canaria, hybrid
BioGeoSCAPES project	• Presentation of NEREA augmented observatory. November 2023, Woods Hole
National Academy of Sciences	• Presentation at the Ocean Sciences Board "ocean integration, challenges for ocean observing". May 2023

Achieved main results

Deliverables		
D3.7	WP3 network harmonization recommendations	✓
D3.8	EuroSea Strategic vision	✓
D3.9	Glider network, European coordination	✓
D3.10	Gliders metadata	✓
D3.11	Eulerian Best Practices	✓
D3.12	Eulerian metadata catalogue	✓
D3.13	EuroSea data handbook	✓
D3.14	HF-Radar Tools	✓
D3.15	Tide gauge metadata catalogue	✓
D3.16	Euro-Argo updated strategy	✓
D3.17	EuroSea data integration	✓
D3.18	Observing Networks final Assessment	✓
D3.19	Omics community protocols	✓
Milestones		
MS30	Ocean integration demo	✓
Internal Milestones		
iMS40	ASV 2nd workshop	✓
iMS41	Tide Gauge 2ndWorkshop	✓
iMS42	HF-Radar 2ndWorkshop	✓
iMS44	R/V workshop	✓

iMS45	Glider workshop	✓
Others (optional)		
Gliders	OceanGliders Github[58]	✓
Eulerian	European Fixed Platform inventory	✓
Sea Level	Permanent Service for Mean Sea Level (PSMSL, NOC) data portal for sea level from GNSS-IR[59]	✓
Sea Level	Data comparison tool[60]	✓
HF-Radar	HOORT tool[61]	✓
Augmented	First set of Metagenomic Assembled Genomes (MAGs)	✓

[58] https://github.com/OceanGlidersCommunity
[59] https://psmsl.org/data/gnssir/index.php
[60] https://www.sonel.org/tgcat/
[61] https://hoort.hfrnode.eu/station-status/?is_operational=&wavelength=&direction_of_arrival=&calibration_type

WP4 - Data integration, Assimilation, and Forecasting

Lead: MOI, CO-lead: UNIBO

Objectives
• Ensure that new or consolidated *in situ* observation data sets from the different networks (WP3) and from the WP5, 6, 7 demonstrator activities are integrated in the European modelling and forecasting systems at different space and time scales, from the Copernicus Marine Service global to the regional North East Atlantic and Mediterranean Sea systems
• Implement ensemble forecasting at regional level to extract Extreme Forecast Indices (EFI) to connect with WP5 and WP6
• Assess the skill of ocean variables from the Copernicus Climate Change seasonal forecasting systems using observable ECVs to develop and provide user-relevant indicators in WP2 and WP7
• Integrate all new products, observational and model data, in the Copernicus Marine Environment Monitoring Service and the Copernicus Climate Change System (C3S) thus reaching TRL7 and 8

Summary of progress towards WP objectives

WP4 completed all remaining tasks and organized the submission of all final deliverables. WP4 has met all the main objectives set at the start of the project. It improved the use and integration of in situ observation data sets in the Copernicus Marine Service modelling and forecasting systems (moorings, gliders, deep and BGC Argo). New ensemble forecasting capabilities have been developed and tested at regional level. This will pave the way for the implementation of operational ensemble forecasts in the Copernicus Marine portfolio (post 2025). Ship-based time series pilot products have been developed and new carbon synthesis products have been delivered. The skill of ocean variables from the Copernicus Climate Change seasonal forecasting systems has been assessed from observations.

Detailed progress per task (or subtasks)

Task 4.0: Coordination

In this reporting period, WP4 had regular online meetings and one hybrid online/face-to-face meeting at the annual project meeting in Cadiz focusing on interactions/synergies between WP4, WP2 and WP3. WP4 partners also exchanged and interacted with other EuroSea demonstration WPs. This also included the participation to EuroSea SC meetings. Towards the end of the project the coordination work was focused on the completion of final deliverables for WP4 and preparation for the EuroSea General Assembly and the high-level Symposium in Paris and final reporting of WP4 tasks.

Task 4.1: Assimilation in the global and North East Atlantic (IBI) Copernicus Marine modelling system and analysis/forecast quality assessment

Task leader: MOI, Partners: EPPE

Early in this reporting period, assimilation experiments were defined with the IBI 1/36° regional system to assess the impact of repetitive glider lines. The experiments were defined to be coherent with the one produced with different other systems involved in task 4.2. Having different model configurations, different assimilation systems looking at the impact of the same data set gives a more robust assessment than a unique simulation. Assessment metrics were also defined in common, including misfit to observations, gliders and others as Argo floats, and transport in key straits. Results with the IBI model highlighted a local sensitivity to

the glider line data assimilation and an improved estimation of the transport and water mass properties in the observed region. The repetitiveness in time of the observations is necessary to have an improved representation of the local variability.

At global scale, a specific study was conducted focusing on the effect of data assimilation in the tropical ocean to see how this improves the intra seasonal process representation. In the tropical regions, moorings are providing high frequency but spatially sparse observations at fixed point, that complement the satellite SST and altimetry observations. The analysis of twin simulations that only differ from the assimilation of observations highlight an improvement of the tropical waves' representation, in terms of celerity and phase.

To improve the accuracy of the Copernicus Marine BGC global reanalysis and forecasting systems, BGC Argo observations were used to optimize the parameters of the PISCES model in its 1D version. This optimization process was performed using observations collected along the trajectory of a specific float in the North Atlantic using an ensemble-based approach. The optimized 1D model outperforms the existing 3D model when compared to observations of chlorophyll, particulate organic carbon, nutrients, oxygen, dissolved inorganic carbon, and alkalinity collected along the float's trajectory.

This methodology has been extended to other geographic regions by using different BGC Argo floats to estimate model parameters in different ocean regions, ultimately resulting in a spatial map of PISCES parameters. These optimized parameters will then be incorporated into the 3D PISCES model.

Articles presenting the results of the optimization experiment in the North Atlantic and results from glider data assimilation experiments conducted in T4.1 and 4.2 are currently in preparation.

Task 4.2: Assimilation in the Mediterranean Sea Copernicus Marine modelling system and analysis/forecast quality assessment

Task leader: CMCC, Partners: OGS, SOCIB

Following the General Assembly in May 2022, results from the previous reporting period were presented in the EuroSea/OceanPredict workshop in June 2022. Later on, new glider assimilation experiments were performed for MedFS and WMOP systems for the intercomparison in deliverable D4.9 which will be used as physical forcing for the MedBFM[62] system to make the impact assessment of physical glider observations on biogeochemistry.

The intercomparison of physical systems is extended to task 4.1 to also include the IBI system. Common diagnostics were developed to assess the impact of the same glider dataset in the western Mediterranean Sea on these different analyses and forecasting frameworks.

In MedBFM, experiments were performed to test the physical forcing with and without glider assimilation. Moreover, the assimilation of BGC gliders is tested in MedBFM to assess their usefulness and consistency with other in-situ profiles (i.e., BGC-Argo).

The progress on the assimilation of physical gliders in the western Mediterranean Sea and the assessment of their impact on the MedBFM system was documented in two reports (deliverable D4.9 and D4.10). The experiments assimilating the BGC gliders were also documented in the respective deliverables.

[62] https://doi.org/10.1016/j.cageo.2019.01.003

Several virtual meetings were organised to discuss data assimilation and model intercomparison results. In addition to the article already mentioned in task 4.1 above, another article on the impact of physical assimilation on MedBFM is in preparation.

Task 4.3: Model development and validation for improved forecasting

Task leader: UNIBO, Partners: SOCIB, CMCC

The task team successfully implemented a first version of an operational ensemble prediction system (EPS) for the Mediterranean Sea. The initial-condition (IC) EPS had been developed from a previous version of the modelling infrastructure used for the operational forecasting system of the EU-sponsored Copernicus Marine service. The development of EPS was carried out in the first 18 months of the project and already described in the previous report. Each ensemble member is forced by ECMWF surface fields and forecasted the same 10-day period starting from different initial conditions, taken from the ocean analyses of the preceding 10-days period. This IC-time-shifted ensemble scheme allowed us to explore the forecast dependency from both the IC and the atmospheric forcing (i.e., ECMWF). The partners presented the available products, which also included two extreme forecasting indices, one for sea surface temperature and one for sea level. They have also produced a first validation of the ensemble forecasting system using both model analysis field and independent new data. This last type of validation was performed together with partners from Balearic Islands Coastal Observing and Forecasting System (SOCIB) and was possible through comparison with glider observations taken from SOCIB in the Ibiza channel (western Mediterranean). Results of the Mediterranean EPS were presented at final EuroSea meeting in Paris.

Deliverable D4.11 on Evaluation of Extreme Forecast Indices (WP5+6) was submitted in September 2023. The deliverable presents the first ever application of the Extreme Forecast index (EFI) approach to numerical ocean forecasting. The EFI are computed from the EPS developed in previous reporting periods, that is a first implementation of a forecast ensemble system that is being developed for the Mediterranean Sea Monitoring and Forecasting Center of the Copernicus Marine Environment Service. The EPS has been running in a pre-operational setting since late 2022, and its outputs are freely accessible using a web interface[63] where a suite of maps and other diagnostics can be visualised. We analysed the EFI definition adopted and we discussed its application to SST and sea surface height (SSH) extremes. A series of interesting marine events that occurred in the year 2021 are also analysed through the lens of the EFI approach. An article presenting the first implementation of an operational ensemble prediction system for the Mediterranean Sea is under preparation.

Task 4.4: Improving the use of in-situ observations for the long-term validation of satellite observations

Task leader: CLS, Partners: AZTI, ACRI, CSIC

Time period: 1 May 2022 – 31 October 2022

Task 4.4 is divided in 4 subtasks, all aimed at the validation of either height, velocity or ocean colour for Sentinel-3 A&B using in-situ or other satellite mission data. The first subtask deals with SOCIB glider data in the Balearic Sea (CSIC), followed by the use HF radar and ADCP in the Bay of Biscay (AZTI), then globally with the Argo in-situ observations (CLS) and finally BGC Argo array for the validation of ocean colour satellite

[63] https://medens.cmcc.it/

missions (ACRI-ST). Preliminary results were presented at the EuroSea annual meeting held in Cadiz (Spain) in May 2022. Final results were reported in deliverable D4.5.

Validation of Sentinel-3 altimeter observations with SOCIB glider data in the Balearic Sea (CSIC)

This substask aimed to validate Sentinel-3A altimeter observations along track 57 track March-April 2021 with glider observations in the Balearic Sea. Dynamic height (DH) and velocity calculations and filtering, and derivation to compute velocities are performed, and a correlation coefficient, root-mean-square-error (RMSE) and RMSE-based score (RMSEs) are used as metrics for comparisons. Results show mainly good agreement except in salinity front not captured by altimetry. The glider-derived geostrophic velocity is compared to the DAV (depth-averaged-velocity) computed from the GPS glider positioning. The across-track components of both fields show a similar shape, while there are significant differences in their magnitudes. Dissimilarities between both fields are expected because they represent a different physical content.

Validation of Sentinel-3 altimeter observations with HF radar and ADCP in the Bay of Biscay (AZTI)

This subtask aimed to compare altimetry data with an HF radar and an ADCP in terms of current velocities. To that end, first, the altimeters and tracks that could be used in the comparisons and the amount of data that they provided were evaluated. Then, after exploring different approaches to carry out the comparisons the along-track current comparisons and the triple collocation were selected.

First, the along-track comparison was performed, where HF radar-derived and altimetry-derived currents were compared in across-track direction along the altimetry tracks. For that, the data from each observing platform were processed in order to match as much as possible the currents derived from them. Different statistical results such as correlations and root mean square differences were obtained for areas of different current dynamics. This enabled to identify appropriate scenarios/conditions for the validation of altimetry measurements with HF radar data in coastal areas.

Then the triple collocation was performed by pointwise comparing HF radar, ADCP and altimetry-derived currents in the area where the ADCP was located. The initial results indicated that the data triplets needed for applying the method were few and thus an additional altimetry point was considered providing more data triplets. After several additional tests and adjustments, the results provided information about the random error of altimetry and HF radar considering the ADCP as perfectly calibrated.

In addition to the analyses, a poster was presented at the EuroSea annual meeting held in Cadiz (Spain) in May, showing the obtained results.

Global validation of altimetric data (Sentinel-3) with in-situ observations (CLS)

The main objective of this sub-task was to validate altimetry data at global and regional scales, along track Sentinel3B (S3B) altimeter observations in terms of sea level and current using two global ocean observing systems: Argo and surface drifters. The triple collocation analysis (TCA) was applied to estimate the random error associated with the altimeter measurement. In addition to the triple collocation analysis, usual validation metrics (e.g. rms, bias, correlation) were also retrieved. The main task was the pre-treatment of the data to select significant collocated matchups and it required expertise in scales and variability of the observed signals to process them (dynamic height calculations, projections of velocity across track, matchup selection, filtering). The validations were performed over year 2019 and were applied to sea level anomalies and geostrophic velocities anomalies. These validations showed the importance of in-situ data to validate altimetry and that a homogeneous time and space distribution is important to compare the datasets.

BGC Argo array for the validation of ocean colour satellite missions, in particular S3A&B (ACRI-ST)

Chlorophyll, the Kd and the Bbp from BGC-argo floats were extracted and made the matchup with OLCI data to apply the triple collocation technique to try to estimate the error associated to the measurement. The calculation of an in-situ climatology of Chlorophyll based on BGC-argo measurement was limited by the number of observations. The quality of OLCI satellite observation of ocean colour is analysed thanks to BGC-argo floats on regional and global scale, with the objective to tend toward validation of satellite products. This work was presented at the Living planet symposium in Bonn in 2022.

The task team presented their work as a poster at the EuroSea final General Assembly in September 2023.

Task 4.5: Synthesis product development based on ship-based in situ biogeochemical data

Task leader: UIB, Partners: GEOMAR

Task 4.5 is divided into 4 subtasks. In summer 2022, deliverable D4.4 was finalised and GLODAPv2.2022 as well as SOCATv2.2022 were released. Besides updating and improving GLODAP and SOCAT, the overall goal of this task was to complement these products with a synthesis product focusing on marine fixed-point ship-based time-series measurements. Eventually, within the last year of this project, the pilot product for marine fixed-point ship-based time-series measurements could be realised. The corresponding pilot for the "Synthesis Product for Ocean Time-Series" (SPOTS[64]), as well as the accompanying data description paper have been finalised and are presently under revision (Lange et al. 2023 - accepted with minor revisions). The SPOTS pilot provides biogeochemical ship-based time-series data in a data product with a consistent format and semantics that enhances intra- and inter-station comparability while implementing the FAIR principles. The pilot includes data from 12 fixed ship-based time-series programs (Figure 1) with a focus on the Global Ocean Observing System's biogeochemical EOVs. Using the results from Subtasks, 4.5.1 and 4.5.2, the stations' comparability was improved. Altogether, SPOTS' pilot increases the readiness of biogeochemical time-series and facilitates a variety of applications that benefit from the collective value of biogeochemical time-series observations. Looking ahead, it forms the basis for an envisioned sustained living time-series data product that ideally encompasses all available biogeochemical time-series data. More details regarding SPOTS are outlined in the Subtasks 4.5.1 and 4.5.2 below.

[64] https://essd.copernicus.org/preprints/essd-2023-238/

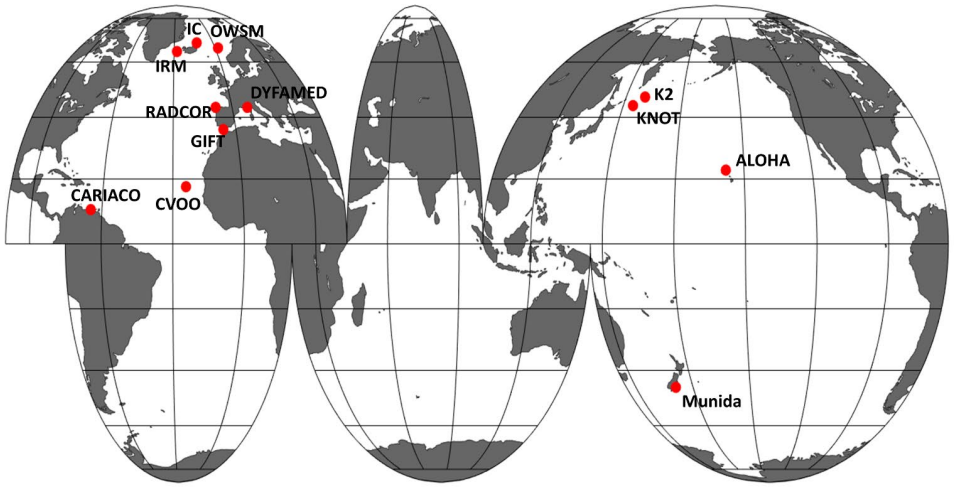

Figure 1. Locations of participating ship-based time-series stations.

Subtask 4.5.1 Develop quality control procedures for data from certain platforms e.g. ship-based time series stations

Deliverable D4.4 has been finalised and submitted, in which an overarching quality control (QC) guideline that has been developed for biogeochemical ship-based time series data is described. The QC guideline is based upon a decision tree model, which leads to the most appropriate statistical QC routine available. The suggested statistical QC routines are categorised from "Best" to "Minimum", depending on their potential to identify bad samples and/or to detect systematic biases. The developed "Regular Outlier Test" (EuroSea milestone MS13) has been evaluated and incorporated and categorised as "Best". Further, the deliverable includes details on assessing the comparability of time-series data by means of in-depth checks of applied methodologies. The corresponding implementation of the general (quantitative and qualitative) quality assessment of time-series data to time-series programs participating in SPOTS started early during this reporting period. Foremost, the work started with the in-depth method checks against community-agreed recommendations (based upon fill-out metadata templates).

Towards the end of the reporting period the quality assessment of all included time-series programs participating in the pilot of SPOTS has been finalised. 'Best-Practice' flags in the data product indicating the comparability of applied sampling and analysing methods, are assigned to all data (Figure 2). The SPOTS accompanying data description paper (Lange et al., 2023 - submitted in June 2023) further details estimated minimum variability indicators, offsets against GLODAP, and provides information on the applied statistical QC used by/for each time-series program. The developed QC guideline (deliverable D4.4) and underlying statistical routines have been applied by the GEOMAR partner to QC of four of the participating time-series programs of SPOTS: the Cap Verde Ocean Observatory bottle data (QC of all data); the Munida Ocean Time-Series (QC of all data); K2 (QC of data post 2010); and KNOT (QC of data post 2010).

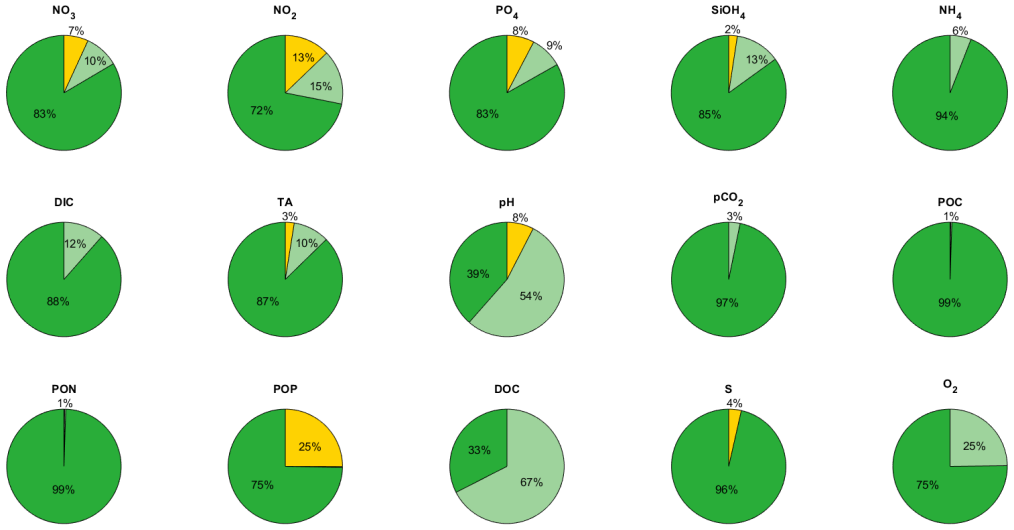

Figure 2. Overview of assigned BP flags. Percentages correspond to the number of samples in the combined dataset. Dark green colours indicate samples that have been measured according to all (incl. "desired") BP requirements, i.e. a BP flag 1. Light green colours indicate samples that have been measured meeting the "Required" BP requirements only, i.e. a BP flag 2. Orange colours indicate samples for which the methods do not meet the BP requirements, i.e. a BP flag 3. Variable synonyms correspond to the product header names.

Subtask 4.5.2 Plan and perform a workshop with PIs from international ship-based and open-ocean BGC time-series sites on data routines

The second SPOTS focused time-series workshop was held successfully in November 2022 with representatives from most of the SPOTS stations present, as well as the lead of the Marine Ecological Time-Series Research Coordination network (METS-RCN), and experts from GLODAP and SOCAT. Besides, agreeing on the last open details regarding method recommendations, and precision- and accuracy estimates, this workshop resulted in a fixed timeline to publish the product (incl. website[65]) and accompanying data description paper. Further, this workshop was used to present and discuss the ongoing collaborative work with the IOC Ocean Data Information System team towards schema.org ship-based time-series metadata.

In addition to the SPOTS focused workshop, the GEOMAR partner participated in the closely related METS-RCN informatics workshop held in January 2023. Here, the interim results of SPOTS were used as template to develop a FAIR (meta)data concept for biological time-series, focusing on schema.org friendly metadata for such data.

Subtask 4.5.3 Integration of those quality-controlled data with the Global Ocean Data Analysis Project (GLODAP).

After initial discussion on possible integrations of SPOTS into GLODAP, it has been decided to keep the two data synthesis products separate, each addressing different stakeholder demands. Nevertheless, a few fixed-point time-series datasets have already been present in earlier GLODAP releases. In a first effort to synchronise the included fixed-point time-series data of GLODAP with the more recent SPOTS data, the

[65] https://www2.whoi.edu/site/mets-rcn/ts-data-product/

'Ocean Weather Station Mike (OWSM)' time-series has been updated in GLODAPv2.2022. Both SPOTS, and GLODAP now include the identical (quality controlled) OWSM data from 2001 until 2021.

Expanding on the effort to synchronise already included fixed-point time-series data in GLODAP with data included in SPOTS, the IrmingerSea and IcelandSea datasets have been updated for GLODAPv2.2023. Now, both data synthesis products include the identical (quality controlled) data of those two stations covering 1983 until 2019 and 1985 until 2019, respectively.

Subtask 4.5.4 Operationalize European SOCAT and GLODAP quality control efforts and test the implementation of the quality control routines for ship-based time-series

GLODAPv2.2022 was published in August 2022, with the two major updates being the addition of 96 new cruises and the full quality control of all sulfur hexafluoride (SF6) data. The task team helped with the collection of new and updated data, performed the 1st and 2nd quality control of the new cruises, discussed the results at the reference group meeting, merged the data for the final product, and generated updated statistics for the accompanying paper (Lauvset et al. 2022). Partner UiB provided the data and needed documentation to Copernicus Marine in-Situ TAC.

Work towards migrating the Matlab 2nd QC crossover toolbox (Tanhua 2015), representing the core 2nd QC method of GLODAP, to an online web application based on the open-source software Django and Python, was carried on. Eventually, once completed, this will display an important fundament for the envisioned versatile and semi-automated ingestion system. SOCATv2022 was released in June 2022. UiB assisted in uploading, assembling and coordination of SOCATv2022. Partner UiB provided the data and needed documentation to CMEMS in-Situ TAC.

GLODAPv2.2023 will be published in October 2023, with the major updates being the addition of 23 new cruises. The task team helped with the collection of new and updated data, performed the 1st and 2nd quality control of the new cruises, discussed the results at the reference group meeting, merged the data for the final product, and generated updated statistics for the accompanying paper. Partner UiB provided the data and needed documentation to Copernicus Marine in-Situ TAC. Work towards migrating the Matlab 2nd QC crossover toolbox (Tanhua 2015), representing the core 2nd QC method of GLODAP, to an online web application based on the open-source software Django and Python, was finalised. The tool can now be accessed online[66]. The corresponding deliverable D4.12 was submitted, describing the migration in more detail. Eventually, this open software will display an important fundament for the envisioned versatile and semi-automated ingestion system enhancing the readiness level of GLODAP (Lange et al., 2023).

SOCATv2023 was released in June 2023. UiB assisted in uploading, assembling and coordination of SOCATv2023. Partner UiB provided the data and needed documentation to CMEMS in-Situ TAC.

Task 4.6: Quality assessment of ocean variables from the C3S seasonal forecasts

Task leader: ECMWF, Partners: CMCC

In collaboration with task 7.2, task 4.6 provided a comprehensive validation of the accuracy and reliability of seasonal forecasts of physical ocean indicators. Two fully-coupled and operational seasonal forecast systems (CMCC-SPS3/3.5 and ECMWF SEAS5), both of which contribute to the Copernicus Climate Change Services (C3S) and are freely-available, were being used. The forecasts are validated against a range of long-term

[66] http://xover.bcdc.no/

climate records for Essential Ocean Variables: satellite-derived sea surface temperature, ocean heat content from global ocean reanalyses and satellite-derived sea level, all of which are available through CMEMS. The validation of the seasonal forecast skill of these indicators was presented in deliverable D4.6 (month 36, last quarter 2022), continuing on from the work on ocean heat content published in January 2022[67].

First, the team provided the global spatial distribution of the skill of the seasonal forecast ensemble mean in terms of anomaly correlation and root mean square error and compared it to the persistence and climatological benchmarks. The analysis of seasonal forecast output is now on par with the atmospheric variables available on the C3S service and used to construct climate services. Then, the partners also went beyond the standard verification metrics to evaluate the ability of the models to represent the observed long-term trends, allowing them to separate the contributions to skill of initial conditions and dynamic capabilities of the forecast systems. Results show that long-term trends contribute to the skill of seasonal forecasts. Although the forecasts capture the long-term trends in general, some regional aspects remain challenging. Part of these errors can be attributed to specific aspects of the ocean initialization, but further research is needed to pin them down. Skill gains can be obtained by improving the trend representation in future forecasting systems. In the meantime, a forecast calibration procedure that corrects the linear trends can produce substantial skill gains. The results show that calibrated seasonal forecasts beat both the climatological and persistence benchmark almost at every location for all initial dates and lead times (Figure 3). Therefore, results demonstrate the value of the seasonal forecasts for marine applications and highlight the importance of representing the decadal variability and trends in ocean heat content and sea level.

Although the task finished after the delivery of deliverable D4.6 in October 2022, the task team stayed involved in the project, submitted a manuscript on the skill of MHWs and attended the final EuroSea meetings in September 2023.

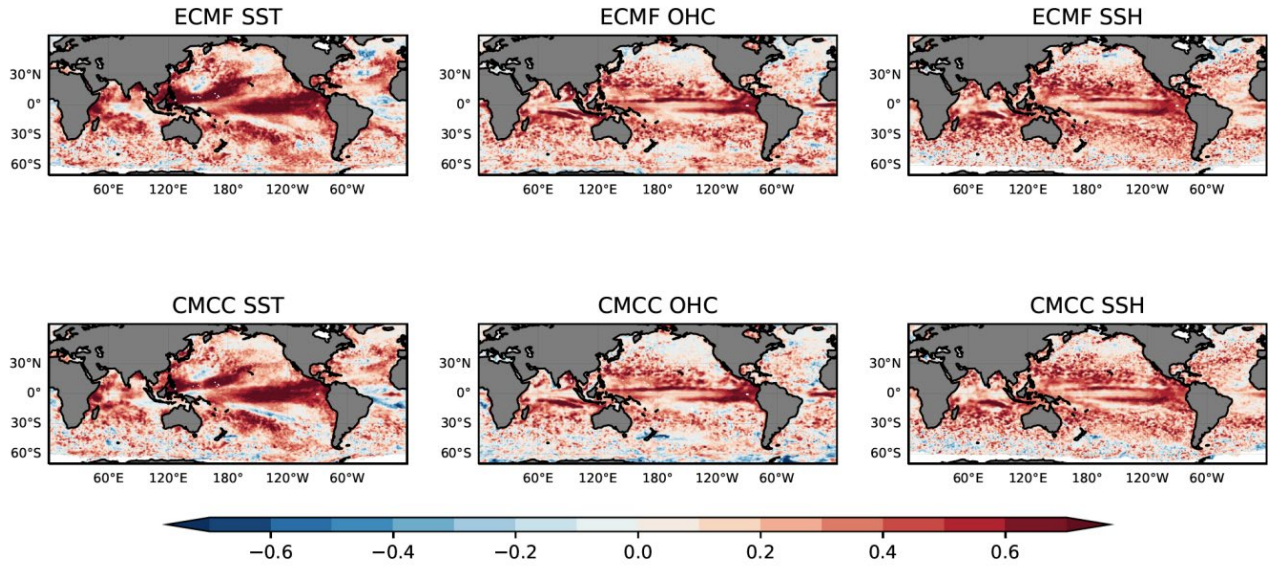

Figure 3. Summary of ACC skill differences of the trend-corrected dynamical seasonal forecasts (ECMWF & CMCC systems) against persistence, for the different variables for forecast initialized in May. Shown are the differences for the first and second seasons (top and bottom respectively). Positive values indicate that the dynamical seasonal forecasts are better than the persistence benchmark.

[67] https://link.springer.com/article/10.1007/s00382-021-06101-3

Cooperation and interaction with other EuroSea WPs

Co-operator	WP activities
WP4/6/7	• Collaboration on Seasonal Forecasting for the Aquaculture Industry (March 2023)

Achieved main results

Deliverables		
D4.4	Quality-control procedures for ship-board biogeochemical time series data	✓
D4.5	Synthesis of satellite validation results	✓
D4.6	Skill assessment of ECV/EOV from seasonal forecast	✓
D4.7	SOCAT Quality Control (QC) procedures	✓
D4.8	Assess impact of observations	✓
D4.9	Intercomparison of glider assimilation in the different analysis and forecasting systems	✓
D4.10	Results of the BGC data assimilation	✓
D4.11	Evaluation of Extreme Forecast Indices (WP5+6)	✓
D4.12	GLODAP Quality Control (QC) procedures	✓
Milestones		
MS2	Design of operational implementation of forecasting system in the Mediterranean Sea	✓
MS21	Validation of forecasting with glider data in the Mediterranean Sea	✓

WP5 - Coastal Resilience and Operational Services Demonstrator

Lead: NOC, CO-lead: EPPE

Objectives
• To demonstrate the end-to-end connection from observations - including a new generation of multi-parametric monitoring station - to their wider availability and use by a wide variety of stakeholders by combining and incorporating existing CMEMS and satellite products into novel decision-making tools for policy and planning

• To develop new coastal management products including the downscaling of ocean analyses and forecasts for port and adjacent cities' operations aiming to:
  ○ Provide an end-to-end demonstrator for climate quality sea level measurement to sea level services with a focus on the Mediterranean, but linked with Africa
  ○ Development and demonstration of integrated observations and models supplying oceanographic services for ports and cities.

Summary of progress towards WP objectives

In relation to task 5.1 (Sea Level Advice Demonstrator), progress towards the WP objectives linked to the installation of the new tide gauges (subtask 5.1.1) was subject to delays during this period. This included deliverables D5.6 (Documentation associated to the capacity building), D5.9 (Operational monitoring systems available at the three sites) and milestones MS14 (Prototype low maintenance multiparametric monitoring at 2 sites) and MS24 (Installation of documentation, including calibration sheets). This was because the delays reported in the second action progress report were further exacerbated by issues such as changes in installation permissions (Barcelona), security restrictions associated with the conflict in Ukraine (Taranto) and visa difficulties due to Brexit which demanded submission of a grant amendment relating to the Barcelona installation. Consequently, the deliverable dates were postponed to August 2023. The tide gauges were installed in Barcelona and Taranto by this deadline and the milestone and deliverable reports for D5.6 D5.9, MS14 and MS24 were submitted on time and will be updated once the Buenaventura tide gauge is installed.

For subtask 5.1.2, the remaining deliverable D5.8 was completed on schedule and a scientific paper based upon this work was published shortly thereafter in the Journal of Geophysical Research: Oceans. Since task 5.1.3 (Data-driven modelling and visualization for sea level guidance) and the associated deliverable (D5.1) had been completed during the previous reporting period, the follow-on work focused upon publicizing the output with the production of a video and press release by ARUP. The follow-on work focused upon publicizing the output with the production of a press release by the University of Cambridge and a paper in Oceanography magazine.

In relation to task 5.2 Oceanographic services at the service of ports and cities (OSPAC), the work on Task 5.2.1 (Model downscaling) has been significantly strengthened and the associated deliverables D5.3 (CMEMS downscaled circulation operational forecast system) and D5.4 (CMEMS downscaled wave operational forecast system) were refined extensively and were resubmitted. For the Buenaventura site, MS15 had not been compromised by the delayed installation of the tide gauge and was successfully submitted on time.

Since the deliverable associated with subtask 5.2.3 (OSPAC software development) was completed in the last reporting period, work in this period has focused on demonstration of the software for the 2 European sites

as part of subtask 5.2.4. This has been successfully implemented and has resulted in a number of publicity and demonstration events.

In this period, Main activities related with the OSPAC service have been focused on the demonstration phase at two European sites (Subtask 5.2.4). End-user feedback has been gathered through a series of on-site and on-line events, plus an extensive survey. Milestone 19 has been completed and its main results can be found in the report "MS19 - First version of the OSPAC service, to be evaluated by the users". Live data streams from Barcelona and Taranto have been incorporated into the software as planned.

The remaining task for completion is 5.2.5 (Demonstration of the tools at a non-European site) and whilst OSPAC cannot be implemented until the downscaled models are running operationally at EPPE and the Buenaventura tide gauge is installed, this is expected to be completed within the next 2 months (November and December 2023). Part of this task demands the implementation of automated sea level quality control software (D5.7) which is underway, but was postponed due to parental leave for an essential member of staff. The deliverable report was submitted on time and will be updated in due course.

There has been cooperation with other WPs, especially with WP8. WP5 has contributed to develop a Business Plan for the OSPAC tool (see results in D8.8 - Business plan for EuroSea demonstrators) and science-policy interfaces (see D8.3 Lessons Learnt on Science-Policy Interfaces).

Detailed progress per task (or subtasks)

Task 5.0: Coordination

WP5 had regular online meetings and one hybrid online/face-to-face meeting at the annual project meeting in Cadiz. WP leaders at EPPE and NOC met and communicated regularly regarding progress, working to resolve issues jointly. WP5 partners actively cooperated and interacted with other EuroSea WPs, especially with WP8 as regards publicity measures, such as press releases for new papers, data portals etc.

Especially in the final year of the project, communication has been more intense between the WP leaders, in order to ensure that deliverables are/were met. They have communicated at least daily to resolve issues. Partners from NOC, EPPE and Nologin met at the EuroSea General Assembly in Paris and although the WP leaders could not attend in person, they were represented by key personnel with responsibility for delivering the remaining work in WP5.

Task 5.1: Sea Level Advice Demonstrator (SLADE)

Subtask 5.1.1: Low cost and maintenance free tide gauges

Task leader: NOC, Partner: EPPE

Tide gauges can capture the whole spectrum of sea level variability from waves, tsunamis, tides and storm surges to the longer-term trends associated with climate change. They therefore fulfil an essential role in hazard warning systems regionally, but there are notable gaps in sea level monitoring networks in the Mediterranean Sea, particularly along the North African coast. This is partially due to the considerable financial cost of implementing and maintaining tide gauges, which means that they often fall into a state of disrepair. Alternatively, they may be installed and maintained to lower (and less costly) standards than the stringent accuracy requirements demanded by the IOC-UNESCO's GLOSS for monitoring sea level rise. In this latter case, they are useful only as an operational early warning tool and cannot be considered to be multi-hazard warning systems.

In addition, as a 2018 survey by the EuroGOOS Tide Gauge Task Team revealed, there were only 17 GNSS receivers co-located with tide gauges in the Mediterranean Sea. As a result, there are large uncertainties in rates of vertical land motion at tide gauges, which hampers the estimation of long-term sea level trends.

Task 5.1.1 aims to address these issues by developing a new standard of low-maintenance tide gauge system, with minimal ongoing operating costs, geared to ensuring system longevity through the use of renewable power, dual telemetry systems for added resilience and the use of above-water sensors to minimise system degradation. In addition, the tide gauge system offers high-frequency sampling for tsunami monitoring purposes, as well as measuring sea level, vertical land motion, atmospheric pressure and a variety of wave parameters both at the coast and in the nearshore area, thus meeting the monitoring needs of multiple stakeholders including port authorities, hazard warning networks, and the scientific community. The tide gauge prototype also exploits a new technique known as GNSS-IR, which allows the measurement of mean sea level whilst simultaneously measuring vertical land movement and can be used at tide gauges to produce continuous levelling information without the extra cost of conventional levelling. This task aims to trial this tide gauge system in 2 locations in the Mediterranean Sea (Barcelona and Taranto), adding bespoke monitoring functionality to suit local requirements. Data are distributed to stakeholders in near-real time via the IOC's Sea Level Station Monitoring Facility and to the internet browser-based Oceanographic Services for Ports and Cities (OSPAC) monitoring and forecasting tool that has been developed in task 5.2.

Barcelona

At the time of writing the second action progress report, the location of the Barcelona tide gauge had been agreed and the system had been manufactured ready for export and installation. It was anticipated that this would take place in April 2022. However, the co-ordinators of a nearby nautical college objected to the proposed location and a NOC engineer was required to attend site and agree a solution with the Port of Barcelona and the nautical college. The planned installation was postponed to June 2022 accordingly. At the same time an indefinite strike by staff at the Spanish Consulate in the UK meant that NOC engineers could not obtain appropriate work permits to install the Barcelona tide gauge as planned. A Spanish company (SIDMAR Estudios y Servicios Oceanográficos S.L.) was procured to install the tide gauge under NOC supervision. This demanded a grant amendment which was submitted in October 2022. NOC engineers produced an installation guide to support this work by SIDMAR.

The grant amendment to subcontract the tide gauge installation was approved in early February 2023, delaying the planned Barcelona installation to March 2023. This also delayed the Buenaventura installation as in-person training of the Colombian technician was planned for delivery during the Barcelona installation. A further ~6-week delay occurred while the NOC obtained fiscal representation in the European Union (necessitated by the departure of the UK from the European Union), to allow the shipping of the tide gauge to Spain.

The tide gauge was finally installed between the 4 and 7 April 2023, during which NOC engineers Steve Mack and Barry Martin supervised the installation of the tide gauge system by engineers from SIDMAR (José María Cortés Crespo and Roberto Sevilla), whilst also training Yosamy García Sanmiguel (DIMAR, Colombia) in installation methods (to support deliverable D5.6). Begoña Pérez Gómez (EPPE) attended to facilitate the process. The installation was completed in accordance with the installation manual provided, the installation process itself was documented in a detailed installation report and the data streams were made live. The completed tide gauge is hosted on 2 sites: (1) the primary site is equipped with the bulk of the monitoring capability for sea level. Air pressure and vertical land motions, (2) the secondary site hosts low-cost GNSS equipment for monitoring significant wave height outside the harbour. These are shown in Figure 4.

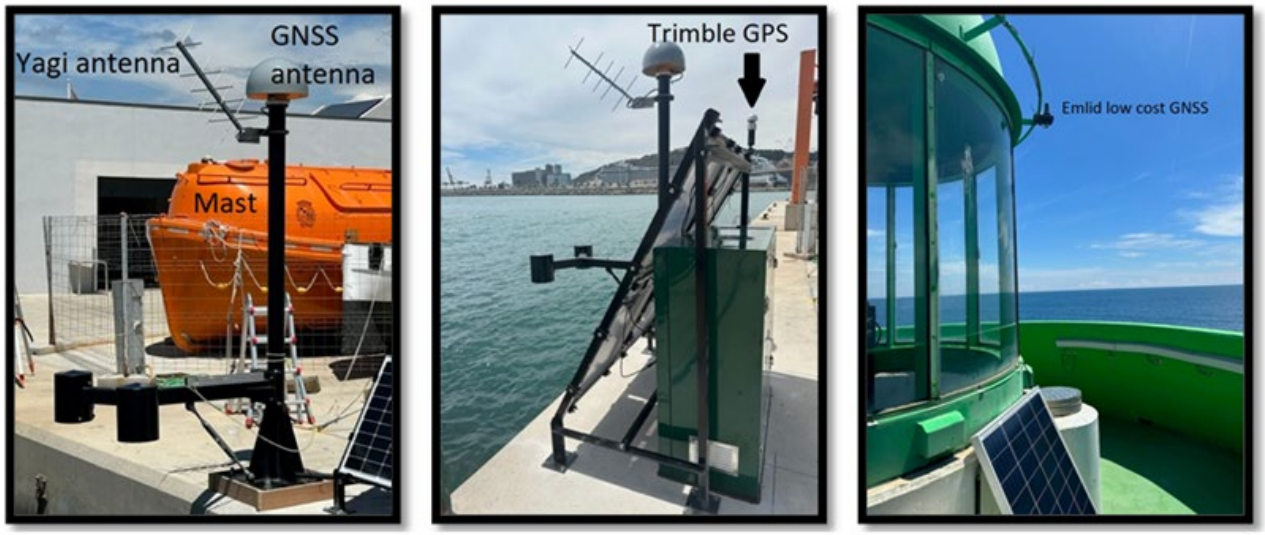

Figure 4. Completed tide gauge installation at Barcelona primary site (left) and (middle) and secondary site (right)

Following installation, a bespoke tide gauge maintenance manual was produced to assist local stakeholders to keep the tide gauge in a good state of repair and was submitted as part of deliverable D5.6.

Taranto

At the time of writing the second action progress report, contact had been lost with local stakeholders and this component of the task was felt to be at risk. In addition, restrictions on foreign travel to Italy (including requirements for quarantine and vaccination status) were not lifted until in May 2022, so NOC engineers were not able to travel to Italy to conduct a site survey to inform system design. The installation was postponed until contact was re-established with the port authority in September 2022 and the installation site was agreed promptly thereafter. It emerged that military operations in Taranto related to the Ukrainian conflict had led to local security restrictions, which had prevented progress locally to identify a suitable installation site for more than 12 months.

Once the tide gauge location was agreed, NOC engineers designed and manufactured the tide gauge system and tested it in the laboratory. An installation manual was prepared to support local partners (CMCC). The system was then prepared for shipping to Italy, but delivery was delayed for ~6 weeks while the NOC obtained fiscal representation in the European Union (necessitated by the departure of the UK from the European Union). There was a further delay whilst the local partner CMCC negotiated the final local permissions and the system was finally installed between 26 and 29 June 2023 by NOC engineers Geoff Hargreaves and Barry Martin alongside Juan Francisco Martinez Osuna and Daniele Piazzolla of CMCC. The installation was completed in accordance with the installation manual provided, with the exception of a customisation to the Yagi Meteosat antenna. It was felt that instead of attaching this antenna to the main 'A' frame of the tide gauge (where it might interfere with the Trimble Alloy GNSS receiver) it would be better positioned on the solar panel frame. The installation process itself was documented in a detailed installation report and the data streams were made live. The completed tide gauge is shown in Figure 5.

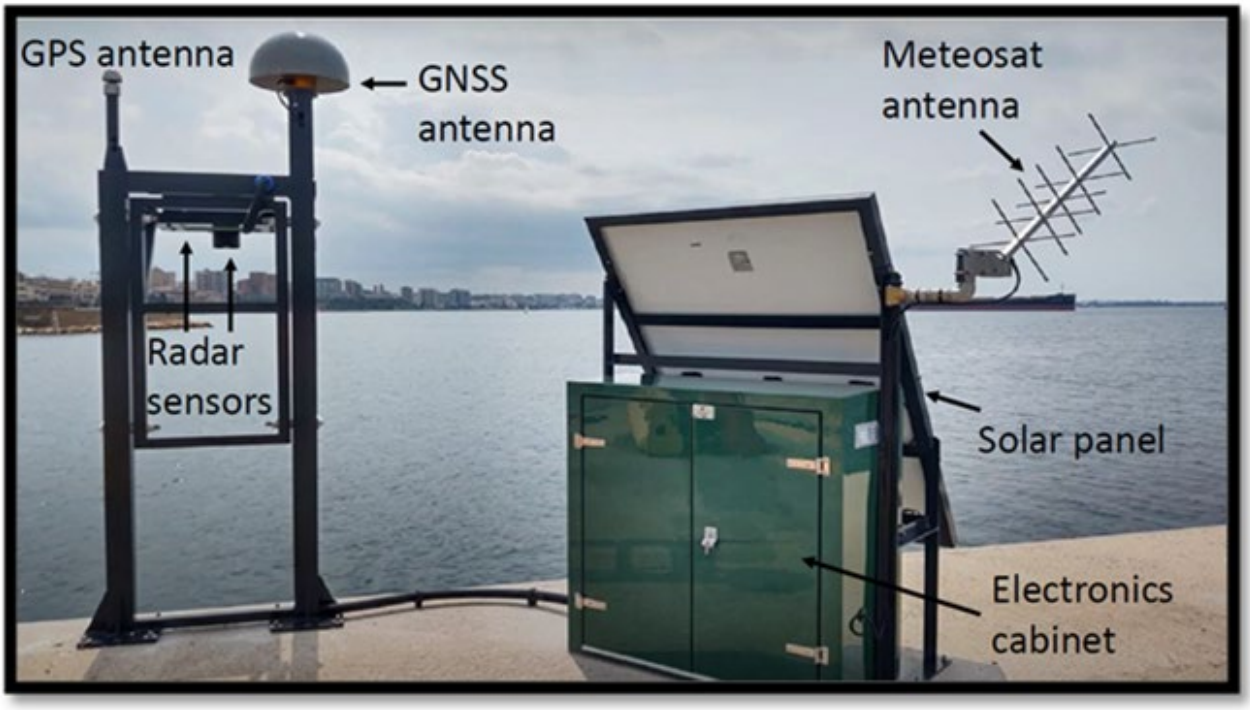

Figure 5. Completed tide gauge installation at Taranto

Following installation, a bespoke tide gauge maintenance manual was produced to assist local stakeholders to keep the tide gauge in a good state of repair and was submitted as part of deliverable D5.6.

Buenaventura

At the time of writing the second action report initial meetings had been held to identify the monitoring requirements of the local stakeholders (DIMAR) and the NOC had produced some draft system designs to allow DIMAR to identify a suitable site to accommodate the equipment. In August 2022, a suitable monitoring site in Buenaventura (Figure 6) was identified by DIMAR. In contrast to the up-estuary location of an existing tide gauge, this site would be exposed to the open ocean, facilitating improved understanding of the relationship between oceanographic processes in the inner and outer bay area. NOC engineers then designed and manufactured the system.

Having manufactured the Buenaventura tide gauge, NOC engineers tested the assembly and then disassembled the equipment for shipping. Between 4 and 7 April 2023 Yosamy García Sanmiguel (DIMAR, Colombia) was trained face-to-face in installation techniques as part of the Barcelona tide gauge installation. An installation manual was also produced in both English and Spanish to assist DIMAR with the local installation of the equipment in Colombia. There was a long delay (March to October 2023) while Colombian stakeholders (DIMAR) arranged the importation documentation and the tide gauge was held in Heathrow airport for several months pending these documents. Shipping was finally permitted on 12 October 2023 and the installation date is expected shortly.

Figure 6. Agreed site for Buenaventura tide gauge installation at Hotel Maguipi. The right panel shows the planned location of tide gauge sensors (red circle) and the supplementary electronics (yellow circle)

Subtask 5.1.2 Optimization of combined tide gauge data and satellite altimetry

Task leader: NOC

The objective of task 5.1.2 is to combine tide gauge data and satellite altimetry for the Mediterranean Sea to overcome gaps in the sea level record. Sea level changes in the Mediterranean Sea show large spatial variation and can deviate significantly both from the global average sea-level rise and it is important to understand this to improve coastal planning for climate change adaptation, but this is complicated by the sparseness of the observational record in time and space. Our main source of information on long-term sea-level changes comes from tide gauge records, but those are spatially sparse, often temporally inhomogeneous, and only located on the coast. In the case of the Mediterranean, nearly all tide gauges are situated in the northern coasts with almost no stations along the African coasts. Satellite altimetry provides a much better spatial coverage but only since 1992. To address the limitations due to data sparseness in the Mediterranean region, this task combines, in a statistically rigorous way, the tide-gauge observations with satellite altimetry data to yield reconstructed sea-level fields with complete spatial coverage and spanning the same period as the tide-gauge record. This work also aims to decompose the reconstructed sea level trends to understand the contribution made by factors such as short-term variability, ocean dynamics, contemporary land-mass changes, and glacial isostatic adjustment (GIA).

At the time of writing the second action progress report, the sea level reconstruction dataset had been produced and a spatiotemporal Bayesian Hierarchical Model (BHM) had been built and used to model sea level as the sum of the four contributions, namely short-term variability (interannual to decadal), sterodynamic changes (ocean dynamics and thermal expansion), GRD (changes in Earth gravity, Earth rotation, and solid-earth deformation due to land-mass changes), and GIA. Basin-averaged estimates and gridded estimates of sea-level change had been produced for all contributory factors. Between May 2022 and July 2022, an analysis of the resulting dataset was completed, and submitted in a deliverable report (D5.8). The Bayesian solutions used to decompose the trends into contributory components were provided via Zenodo[68]. They comprise estimates of sea-level changes, the yearly rate of sea-level change, and the

[68] https://doi.org/10.5281/zenodo.7046702

contribution from each source on a 1/4° × 1/4° grid for the period 1960-2018. The code that implements the Bayesian model was also made available from Zenodo[69], so that updated estimates of sea-level changes can be easily produced as new data comes along by running the provided code on the new data. The work was also submitted to the Journal of Geophysical Research: Oceans and published[70] on 16 September 2022.

This work concluded that spatially averaged sea level over the Mediterranean Sea fell at a rate of -0.3 mm yr^{-1} between 1960 and 1989 which contrasts with rates of global mean sea-level rise in the same period. The fall in sea level during 1960-1989 was largely due to a positive anomaly in atmospheric pressure over the Mediterranean pushing water out of the basin, which previous studies have linked to the NAO. However, even after accounting for the effect of this increase in atmospheric pressure, the rate of sea-level change in the Mediterranean (0.4±0.5 mm yr^{-1}) over that period was still less than half the global average rate (0.9 mm yr^{-1}). This work showed that the low rate was due to the small and opposing contributions from sterodynamic changes and GRD effects. It also found that, since 2000, Mediterranean Sea level has been rising at an increased rate of 3.4±0.3 mm yr-1, which is in line with the rate of global mean sea level rise for that period. This increased rate of rise has been driven by similar contributions from sterodynamic changes and GRD effects. A press release was produced describing these findings and was reported by several UK and international publications, including The Guardian newspaper.

Subtask 5.1.3 Data-driven modelling and visualization for sea level guidance

Task leader: ARUP, Partner: UCAM

The deliverable for task 5.1.3 (D5.1) was successfully met on schedule in April 2021 and work since that time has focused on the development of a video to publicise the completed work (available at Sea level rise insights tool - Arup - Arup[71]) and a press release "Sea change for Hull"[72]. In addition, a paper[73] was submitted and published in the Journal Oceanography describing the work that had been undertaken.

Task 5.2 Oceanographic services at the service of ports and cities (OSPAC)

The aim of task 5.2 is to develop a new coastal service for ports and cities. The OSPAC (Operational Services for Ports and Cities) demonstrator integrates observations and downscaled ocean model forecasts, in order to supply operational oceanographic services for the port cities of Barcelona, Taranto and Buenaventura (Colombia). With this information, it has been created a set of added-value services that can be classified as follows: 1) Visualization and analysis of the observational data, 2) Visualization and analysis of the coastal forecasts, 3) Early warning system both for observations and models, and 4) on-demand services, such as an oil-spill and floating debris forecast system.

Subtask 5.2.1 Model downscaling

Task leader: UPC, Partners: CMCC

During this reporting period, significant advancements have been made by both the LIM-UPC and CMCC teams in the form of resubmitted revised deliverables D5.3 and D5.4. These deliverables pertain to the

[69] https://doi.org/10.5281/zenodo.6797648
[70] https://doi.org/10.1029/2022JC019061
[71] https://www.arup.com/projects/sea-level-rise-insights-tool
[72] https://www.cam.ac.uk/stories/communicating-impact-sea-level-rise-in-hull
[73] Probabilistic Approaches to Coastal Risk Decision-Making Under Future Sea Level Projections, https://tos.org/oceanography/article/probabilistic-approaches-to-coastal-risk-decision-making-under-future-sea-level-projections

CMEMS downscaled circulation operational forecast system and CMEMS downscaled wave operational forecast system. They offer detailed insights into the configuration and implementation of two cutting-edge, high-resolution numerical models specifically designed for the test cases of Taranto and Barcelona, aligning with the EuroSea workplan. Notably, both models have undergone meticulous validation processes, solidifying their status as state-of-the-art tools. The resulting operational services are poised to play a central role within the OSPAC product, a key deliverable of task 5.2.

Model Configuration and Implementation (Subsection 5.2.1.1)

The resubmitted deliverables, D5.3 and D5.4, encapsulate a wealth of information regarding the setup and implementation of advanced numerical models tailored for high-resolution simulations in the geographical regions of Taranto and Barcelona. These models have been meticulously configured in accordance with the specifications outlined in the EuroSea workplan. Detailed descriptions of the model grid, vertical resolution, boundary conditions, and forcing data are provided, facilitating a comprehensive understanding of their design.

Taranto Study Case

The numerical model designed for Taranto exemplifies cutting-edge techniques and parameterizations to capture the intricate dynamics of the region. The documentation accompanying deliverable D5.3 outlines the model's setup, including the selection of physical and numerical schemes, ensuring an accurate representation of circulation patterns and wave processes in Taranto.

Barcelona Study Case

Similarly, the numerical model crafted for Barcelona reflects a high level of sophistication, with a focus on resolving high-resolution requirements. The associated documentation, part of deliverable D5.4, offers detailed insights into the model's grid resolution, bathymetric data, and atmospheric forcing inputs. The Barcelona model has been tailored to effectively capture the unique oceanographic features and circulation patterns within its designated area.

Model Validation (Subsection 5.2.1.2)

A fundamental aspect of the development process involves rigorous model validation. In this context, both numerical models have undergone extensive validation procedures, where model output is rigorously compared against observational data from the Taranto and Barcelona regions. Various metrics, including root mean square error (RMSE), correlation coefficients, and skill scores, have been employed to assess the models' predictive capabilities. The validation results, presented in the documentation, affirm the reliability and accuracy of these models for operational forecasting purposes.

Contribution to OSPAC Product

One of the overarching goals of this work is to enhance the operational forecasting capabilities of the EuroSea project. The operational services generated by the LIM-UPC and CMCC teams' numerical models will serve as integral components of the OSPAC product, a key deliverable within task 5.2. These services will significantly enhance the EuroSea project's ability to provide reliable and high-resolution circulation and wave forecasts for the Taranto and Barcelona regions.

Regarding the work progress in in Buenaventura, Colombia (third pilot site):

Originally slated for Alexandría, Egypt, the LIM-UPC team has successfully achieved and submitted milestone MS15 - a Linux-based PC system with an operational system ready for implementation in a non-European site. This milestone encapsulates all the work carried out within the pilot site in Buenaventura.

Within this milestone, the team has created an offline computational system designed for forecasting hydrodynamics and wave fields specifically tailored to the conditions of Buenaventura Bay in Colombia. This system has been expertly developed and seamlessly installed on a Linux-based PC infrastructure. Additionally, the requisite pre-processing routines have been meticulously crafted to facilitate the seamless integration of the computational system into the broader Colombian Pacific Operational Systems.

Model Validation

The forecasting model, built upon the COAWST platform, has undergone rigorous validation utilising the limited oceanographic data available for the Buenaventura region. Despite the challenges posed by data scarcity, the model has demonstrated its robustness by delivering highly satisfactory results.

Transitioning to Operational Status

With the successful completion of milestone MS15, our computational system stands ready to transition from its current offline status to full operational mode. This achievement marks a significant step towards providing accurate and timely forecasts for Buenaventura Bay, Colombia.

In summary, the LIM-UPC team has met and exceeded the objectives set forth in milestone MS15, advancing the EuroSea Project's goal of implementing a high-resolution forecast system for Buenaventura. The successful development and validation of our model underscore the readiness of our computational system for operational deployment, contributing to improved safety and decision-making for the region.

The validation results demonstrated strong agreement between observed and modelled sea levels, with high correlations, low RMSE, and minimal bias. While surface currents showed slightly lower correlations, they were still deemed acceptable. Snapshots of SST and surface currents from the COAWST system were also provided, with the expectation of improved performance when using DIMAR regional operational products.

Finally, this progress report underscores the successful development and deployment of the forecast system for Buenaventura, Colombia. The system has shown promising validation results and is poised for further enhancements through the integration of operational data.

Subtask 5.2.2 Instrumentation deployment at test sites

Task leader: NOC, Partners: EPPE, CMCC

Progress as regards this subtask is reported under 5.1.1 above.

Subtask 5.2.3 OSPAC software development

Task leader: Nologin, Partners: EPPE, CMCC

The development of OSPAC was completed in the period held by Action Progress Report #2 (month 15-30). Since then, main work has been focused on the demonstration of the OSPAC service at Barcelona and Taranto cities and harbours.

Subtask 5.2.4 Demonstration of the tools at two European sites

Task leader: EPPE, Partners: NOC, CMCC, Nologin

Once finished with the OSPAC developments (subtask 5.2.3), the service entered into a demonstration phase at Barcelona and Taranto cities and harbours. The service was launched on 26 October 2022, as an on-line launch for the Administrators of the Barcelona pilot site (Barcelona Harbour and Barcelona City Council). The service has been disseminated at a series of events, e.g. at the World Ocean Council 2022 in October 2022 where Susana Pérez-Rubio (EPPE) and Manuel García-León (Nologin Consulting) were keynote speakers at

session "SMART Ocean-SMART Industries: Ocean and Climate Data Collection from Vessels, Platforms and Cables during the UN Decade of Ocean Science and Beyond"[74]. In addition, specific user feedback has been gathered.

Since then, the demonstration phase for the Barcelona and Taranto cities has continued. The OSPAC service has been opened to the general public since the hard-launch event held at Barcelona in March 2023. The service has been disseminated at a series of events, and specific user feedback has been gathered:

- Hard launch (27 March 2023): Begoña Pérez, Susana Pérez and Manuel García León. On-site launch at the Barcelona harbour. The Administrators designated at the soft launch can register any interested user to the already available modules
- User feedback survey (April & May 2023): On-line survey for gathering feedback from the users.
- EuroSea 3rd Anniversary Webinar: Marcos García Sotillo (Nologin): EuroSea 3rd Anniversary Webinar / Panel 2: – Leverage your strengths – Innovations in European ocean observing and forecasting benefit society, 24 November 2022.
- COSS-TT Coordination Meeting (May 2023): Sotillo, M.G., García-Valdecasas, J.M., Gallardo, A., Drevillon, M., Amo, A., Lin-Ye, J., Ciliberti, S., Aouf, L., Ballesteros, O., Toledano, C., Alonso, R., Rey, P., Pascual, A., Pérez, B., Asensio, J., Espino, M., Castrillo, L., De Juan, M., García-Valdecasas, J., Serrano, V., García-León, M., Aznar, R. (2023) Nologin Oceanic Weather System: Delivering operational services for the Copernicus Marine and developing coastal downstream applications in the European North East Atlantic, COSS-TT Coordination Meeting, 2-4 May 2023, Montréal, Canada
- PredictOnTime: First Workshop on Observing and Predicting the Global Coastal Ocean (May 2023): On Friday, 12 May 2023 (10:30 – 10:45), Begoña Pérez and Susana Pérez (Puertos del Estado, EPPE) gave an on-line contribution called "OSPAC: Oceanographic services of ports and cities"[75] (https://predictontime.org/workshop-11-13-may-2023/)
- Ocean Race Genoa 2023 - Ocean Data Week, EuroSea event: Towards a user-focused, interdisciplinary, and responsive European ocean observing and forecasting system: Jun 28 2023: Begoña Pérez: "From operational oceanographic services along the Spanish coast to EuroSea OSPAC tool".

The OSPAC implementation in Taranto site has been available in EPPE since April 2023 (pre-production), and moved to production (open to the general public) in July 2023. It provides forecasts of waves, sea level, currents, temperature and salinity, based on the downscaled models developed by CMCC, as can be seen in Figure 7 and Figure 8.

[74] https://www.sustainableoceansummit.org/sos-program/
[75] https://predictontime.org/workshop-11-13-may-2023/

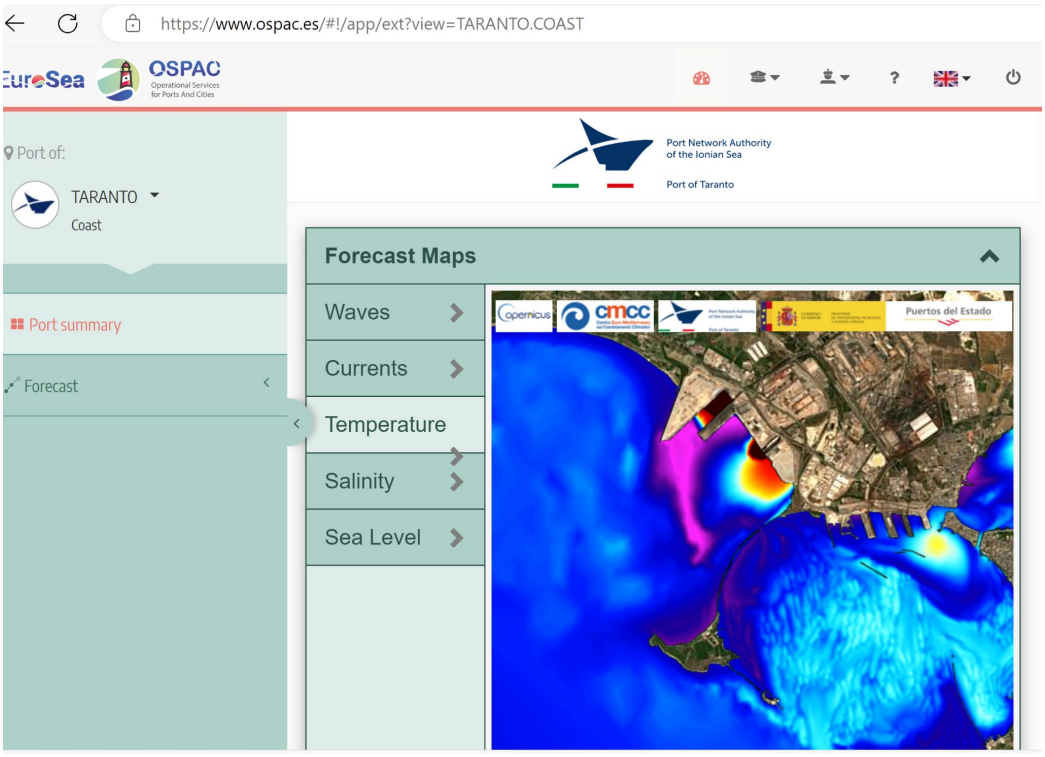

Figure 7. Snapshot of the port summary shown for OSPAC in Taranto site (sea surface temperature).

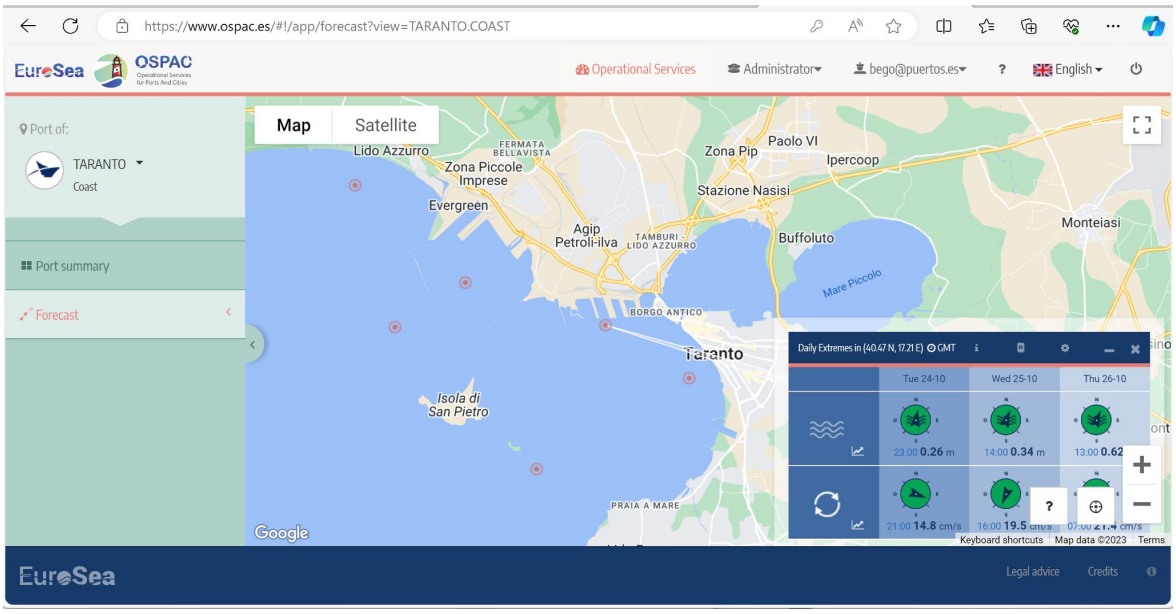

Figure 8. Snapshot of the forecast points available in OSPAC for Taranto site (waves and currents forecasts).

The low-cost tide gauge and the GNSS in Taranto has already been installed (task 5.1.1) and the data are being transmitted in real time to EPPE, for integration in OSPAC and validation of the models. Minor format problems with one of the sensors must be solved before a final display in the tool is available. This is expected to be solved within the remaining two months of EuroSea.

Subtask 5.2.5 Demonstration of the tools at a non-European site

Task leader: EPPE, Partners: NOC, CMCC, Nologin

Several meetings were held between the partners involved in the modelling and instrumentation tasks and DIMAR colleagues, prior to implementation of the OSPAC tool in Buenaventura. This task cannot be completed until the models developed by LIM/UPC are running operationally at EPPE. The tide gauge developed by NOC has not been installed yet but it is on its way to Colombia at the moment of writing this report (October 2023). Once the data are entering operationally EPPE infrastructure, OSPAC for this non-European site will be implemented and demonstrated (over the next two months of the project).

Cooperation and interaction with other EuroSea WPs

Co-operator	WP activities
Marine Institute	• Development of the Business Plan for the OSPAC service (see results in D8.8 - Business plan for EuroSea demonstrators)
EuroGOOS	• Contribution to science-policy interfaces for cities and harbours (see results in D8.3 - First version of the OSPAC service, to be evaluated by the users)

Achieved main results

Deliverables		
D5.6	Documentation associated to the capacity building	✓
D5.7	Automated tide gauge data quality control software and report	✓
D5.8	Mediterranean trend and acceleration sea-level estimates (reduced uncertainty, recalculation toolbox)	✓
D5.9	Operational monitoring systems available at the three sites	✓
Milestones		
MS14	Prototype low-maintenance multiparametric monitoring at 2 sites	✓
MS15	Linux based PC system with operational system ready to be implemented in nonEuropean site	✓
MS19	First version of the OSPAC service, to be evaluated by the users	✓
MS24	Installation of documentation, including calibration sheets	✓

WP6 - Ocean Health Demonstrator

Lead: MI, CO-lead: CSIC

Objectives
• Develop a shared understanding of water management among end-users in Aquaculture, Fisheries, Tourism, Environmental Agencies and Scientists by working together to co-create products that help to identify and foresee "Extreme Marine Events" threatening marine ecosystems, resources, and related businesses, and supporting adaptive management decisions
• Demonstrate the value of ocean observing and forecasting of "Extreme Marine Events" at local to regional scales by developing downstream products and services to assess marine ecosystem health, and provide an early warning system to support sustainable Blue Growth industries and food security needs.
• Provide a new perspective for environmental managers and policy makers focused on maintaining healthy marine ecosystems in harmony with human activities supporting stronger local and regional governance by using EuroSea decision support tools to assess ocean health
• Support the sustainable development of ocean observing and forecasting systems to monitor ocean health by stimulating international ocean observing initiatives
• Create new market and management opportunities for the private sector by co-creating new ocean products for aquaculture and fisheries

Summary of progress towards WP objectives

Between May and October 2022, WP6 progressed well toward meeting these objectives with two WP6 led milestones and two deliverables submitted. While most of the involved co-developers were embedded in the project from the start, a new partnership was formed in this period with the large aquaculture company AVRAMAR[76]. Multiple meetings with EuroSea partners and co-developers in industry (e.g. aquaculture) and policy (e.g. HELCOM, EPA) took place to discuss and exchange information on requirements, EOVs Indicator development, existing and new in situ observing systems in WP6 demonstrator regions. New and enhanced online tools were developed and/or fine-tuned for regions in the north-east Atlantic[77], Mediterranean Sea[77],[78],[79],[80],[81]. These web-based tools are maintained to ensure system operability, and are continuously improved (e.g., addition of extended ocean datasets and diagnostics as they become available). New platforms were developed to enhance the observing system with the successful deployment of 2 EuroSea data buoys (north-east Atlantic; Mediterranean Sea) & ship-based data assimilated into models (Baltic). New data flows were created from the EuroSea in situ buoys to Copernicus Marine Service (with assistance from WP4) and ship data assimilated into models facilitating a more comprehensive delivery of marine information to policy makers in the Baltic and supporting the sustainability of the observing and monitoring system. The improved Baltic Sea model developed through the assimilation of in situ data (oceanographic cruises by multiple nations) and reanalysis in order to support environmental assessments and monitoring efforts

[76] https://avramar.eu/
[77] https://eurosea.marine.ie
[78] http://eo.csic.es/marine-observatory
[79] Mediterranean Surface Exploration Tool, https://apps.socib.es/MSET/
[80] Sub-regional Mediterranean Sea indicators, https://apps.socib.es/subregmed-indicators/
[81] Sub-regional Mediterranean Marine Heat Waves, https://apps.socib.es/subregmed-marine-heatwaves/

(HELCOM-BOOS). An intercomparison study of a number of marine sensors was carried out to determine what sensors were most suitable for the development of a future fisheries observing network.

In the remaining project time (November 2022 – October 2023) WP6 continued to address the project objectives with one WP6 led milestone and five deliverables submitted. WP6 partners were also heavily involved in the development of a WP8 deliverable on the "Business plan for EuroSea demonstrators" (D8.8) which fed into the WP6 "Sustainability and Business Plan" (D6.5).

The WP6 team continued to develop the Marine Observatory for Aquaculture web platform[77] using a number of existing (Copernicus Marine Service) and new data products developed in WP6 and linking the web platform user to other EuroSea downstream data products (e.g. those developed in WP4). In collaboration with WP1 colleagues, WP6 created a "good practice" to document steps needed to set-up a bespoke web application "Marine Observatory for Aquaculture" to help facilitate the transfer of knowledge and make it easier for others to do something similar in other regions. This web platform contains data products as defined through multiple iterations in the design and content by our co-developers in aquaculture with data flows from the EuroSea data buoys, EuroSea Copernicus Marine Service products and other improved EuroSea relevant products and satellite data products.

Detailed progress per task (or subtasks)

Task 6.0: Coordination and co-development

Leader: MI & CSIC, Partners: CSIC, SOCIB, DMI, TalTech, Xylem, IOC-UNESCO

The WP leaders met regularly to monitor progress and document actions to follow-up before the EuroSea SC monthly meetings and ensure milestones and deliverables were submitted to the EuroSea coordination office. WP6 partners met at least once a year, with subgroups meeting and interacting more frequently to achieve activity deadlines. A number of WP6 partners are involved in activities across EuroSea WPs, e.g., indicator development (WP6-WP2) and the MHW task team (WP2, WP4, WP6, WP7) who are also involved in the UN Decade MHW exemplar under the umbrella of the Ocean Observing co-design programme. All partners spent a lot of time interacting with WP6 co-developers in order to ensure outputs of the demonstrator are fit-for-purpose (see individual tasks for further information). The EuroSea cloud was used to share files. WP6 provided support in the form of chairing and as rapporteurs for a session at the EuroSea/OceanPredict Workshop on Ocean Prediction and Observing System Design for the UN Ocean Decade (29 June to 01 July, 2022). Towards the end of the project, meetings became more regular with WP leader meetings once a week and also more frequent co-developer meetings.

Task 6.1: Extreme Marine Events" Ocean Observing & Forecasting

Task leader: MI, Partners: CSIC, SOCIB, IOC-UNESCO, Co-developers: MOWI, EPA Ireland, BIM, NPWS, GlobalHAB, MI Benthic ecologist and fisheries scientists

A report on the "Connections between Extreme Marine Events and Biological EOVs" was submitted in July 2022. This activity examined, through different case studies, the impacts of ocean warming, deoxygenation and acidification on biological communities. Marine biota data investigated in EuroSea included information on seabed habitats, macroalgae, aquaculture (salmon, oysters, sea lice), cold water corals and tuna.

Development and implementation of user-friendly applications for the monitoring and visualisation of Essential Ocean Variables and derived indicators (including marine heat waves) in the Mediterranean Sea providing relevant information to diverse ocean stakeholders at regional, national and local scales: 1) the

"Mediterranean Surface Exploration Tool"[79] for exploration and visualisation of oceanography data in the western Mediterranean Sea, 2) the "Sub-regional Mediterranean Sea indicators"[80] tool (Juza and Tintoré, 2021) for the monitoring and visualisation of multivariate and sub-regional ocean indicators in the Mediterranean Sea and around the Balearic Islands, which provides continuous and timely information on the ocean state and variability at daily (events) to interannual/decadal (climate) time scales, and 3) the new "Sub-regional Mediterranean Marine Heat Waves"[81] tool (Juza et al., 2022) which provides continuous and timely information about marine heat waves at sub-regional scale in the Mediterranean Sea, from event detection in real-time to long-term variations in a context of global warming (since 1982). These web-based tools are maintained to ensure system operability, and are continuously improved (e.g., addition of extended ocean datasets and diagnostics as they become available).

Task 6.1 partners continued to work on the development of the EuroSea Marine Observatory for Aquaculture web portal[77] to display oceanographic data and ocean warnings. The objective of this portal is to provide stakeholders from the aquaculture industry with observations and forecasts on the oceanic conditions impacting fish health and working conditions at the farms. Following the deployment of two ocean monitoring stations at Deenish Island, Ireland (April 2022) and El Campello, Spain (September 2022), the development of this integrated observatory combining in-situ & remote-sensing observations and model forecasts started. The portal not only provides access to near-real-time observations, forecasts and warnings, but also to historical data and Messaging Service warning alerts direct to the users. A Good/Best practice on how to develop similar applications was described in deliverable D6.3 (Best Practice on creating "Extreme Marine Events" Hazard maps & forecasts report). In addition, a related manuscript was submitted to Frontiers in Marine Science "Best Practices in Ocean Observing" and is currently under revision. This new application was co-created with stakeholders to fit the needs of end users in the aquaculture industry.

To facilitate the co-creation of EuroSea downstream products & Services with customers, 13 meetings with different partners (paid and unpaid) across EuroSea WP6 participants, aquaculture specialists, chemists, fisheries scientists, benthic ecologists, Irish EPA representative, National Parks and Wildlife Service representatives, the Irish fisheries board (Bord Iascaigh Mhara) and Aquaculture industry representatives were undertaken.

In order to present the new marine observatory to the stakeholders in the aquaculture sector, two workshops were organised on 30 June and 14 July, 2023. During these workshops, the usage and functionalities of the portal were described. Feedback was collected from stakeholders, and further end users' input was obtained from the questionnaires available on the portal. This feedback proved useful to understand the level of end users' satisfaction and to adjust the portal to their needs. This work has been presented in milestone MS29 (End User Satisfaction Ratings Reported), achieved on 29 September 2023.

To enhance collaboration and interaction between partner institutions, two one-month-length scientific visits were carried out to transfer knowledge during this period between ICMAN-CSIC and Marine Institute in August 2022 and March 2023. The scientific personnel exchanges focused on the development of the observatory described above and the applications of Machine Learning in ocean forecasting. In addition, a visit to the AVRAMAR aquaculture installations in El Campello was carried out in March 2023 to enhance communication between the stakeholders in the aquaculture sector and the scientific partners in the project. This interaction was useful to understand the most up-to-date technology available in the farms and the current needs of the aquaculture industry.

A white paper on “Addressing Sargassum influxes as a ‘wicked problem’” provides information on the state of knowledge on the phenomenon of Sargassum influxes related to biomass estimation and spatial distribution of pelagic sargassum, linkages between physical factors and bloom events and drivers responsible for the continued proliferation of pelagic sargassum in the Tropical Atlantic. A gap analysis was carried out to identify areas that need attention and recommendations for future research.

WP6 actively contributed to the dissemination of WP6 results: Progress in task 6.1 was presented at the EuroSea Annual Meeting 2022, Cádiz, in May 2022. WP6 partners were part of the organising committee of the EuroSea/OceanPredict Workshop on Ocean Prediction and Observing System Design for the UN Ocean Decade, 26 June to 1 July with WP6 colleagues chairing a session and presenting task 6.1 outputs. Task 6.1 was also presented at the ICES ASC 2022, Dublin, 19 - 22 September 2022. These communications focused on the contents of deliverable D6.1. In addition, personnel from ICMAN-CSIC and the Marine Institute attended the Sustainable Ocean Summit & Global Blue Finance Summit 2022, Barcelona, 17-19 October 2022 for networking and communication of the early works on the development of the EuroSea Marine Observatory for Aquaculture. WP6 engaged with the Ocean Decade Co-Design Workshop: Ocean Observing Co-Design exemplar group on Marine Heat Wave, 7-9 June 2022 (Presentation, chair of session, interactive discussions etc.). WP6 partners participated in the Ocean Practices: OBPS Workshop VI in October 2022 (Presentations and Discussion).

Activities related to the EuroSea Marine Observatory for Aquaculture were communicated to industry at the Spanish National Aquaculture Conference, Cádiz, Spain, 21-24 November 2022 (Poster: Application of marine sensors for diagnosing and forecasting extreme marine events affecting aquaculture facilities) and the scientific community at the EGU23 General Assembly, Vienna, Austria, 23-28 April 2023 with the oral presentation “An Observational and Warning System for the Aquaculture Sector in European Waters” as well as collaborative work carried out between EuroSea partners and colleagues from the ICMAN-CSIC (external to EuroSea) with an oral presentation “Monitoring the 2020 storm Gloria in the Ebro Delta (Western Mediterranean) using Earth Observation data”. This collaborative work was also presented at the ASLO Aquatic Sciences Meeting, Palma de Mallorca, Spain, 4–9 June 2023 (Poster: Storm Gloria in the Ebro Delta (Western Mediterranean): Landsat 8 and Sentinel 2 satellites to monitor its impact). Various WP6 colleagues presented work at the EuroSea General Assembly and High-Level Symposium, in Paris, from 18-22 September 2023 during the WP6 – Ocean Health Demonstrator presentation and panel discussion, respectively, with poster communications “An Observational and Warning System for the Aquaculture Sector in European Waters”, and “Application of marine sensors for identifying and forecasting extreme marine events affecting aquaculture facilities”, and contributed to the EuroSea-Co-Design Legacy Session at EuroSea General Assembly (oral presentation Co-designed Ocean Health Observing Services). Finally, outputs from task 6.1 / task 6.4 (EOV requirements, buoy deployments, web platform and stakeholder engagement process) were communicated as an oral presentation Co-development of an Ocean Observatory with the Aquaculture Industry at the 10th EuroGOOS International Conference, Galway, Ireland, 3-5 October 2023. In addition, a promotional video describing the overall tasks within WP6, task 6.1 / task 6.4, outlining main objectives, the deployment of the monitoring stations and the development of a marine observatory was presented at the EuroSea General Assembly and is available on YouTube[82].

[82] “An Observational and Warning System in European Waters: Buoy Deployment in Ireland & Spain”, https://www.youtube.com/watch?v=JwBdvDDtQNk

Task 6.2: Connecting CMEMS and fishery communities to increase uptake, and inform development of products for fishery management

Task leader: CSIC, Partners: MI, Co-developers: IEO-CSIC, ICES WGHANSA, JRC fisheries scientists/modellers

Progress was made on the small pelagic species, Chub Mackerel, a fish stock that has yet to be scientifically assessed for management purposes although the importance of Chub Mackerel has grown significantly in recent years due its commercial value. Chub Mackerel seems to have a wide geographic distribution, from Morocco/the Canary Islands fisheries bank, to Galicia in northern Spain. Early in this reporting period, work on analysing the population dynamics in the Canary Islands fisheries bank off the Moroccan coast began, with initial results showing correlations with environmental variables extracted from Copernicus Marine Service. This work has advanced to include environmental variable information in the population dynamics models, resulting in a publication (June 2022) entitled: "Stochastic Modelling to Assess External Environmental Drivers of Atlantic Chub Mackerel Population Dynamics"[83]. In June 2022, this work was presented to, and reviewed by the ICES WGHANSA and included in their latest report. In addition, EuroSea WP6, Diego Álvarez, as an invited guest speaker, participated in the ICES Annual Science Conference 2022 with a talk entitled "Linking ocean observation and fisheries assessment, challenges and opportunities" during the network session "Advancing the pathways for oceanography to ecosystem science and advice".

A final report (deliverable D6.4 - Linking oceanographic products to fisheries advice; submitted in October 2023) examined how fish populations live in a continuously changing environment and the success for their reproduction and recruitment into the population are determined, to a certain degree, by a combination of different environmental factors. In ever rapidly changing marine ecosystems, it is fundamental to better link the impacts of changing conditions with fish stock fluctuations, particularly for short-lived species, such as small pelagics.

During this reporting period, work was carried out in collaboration with ICMAN-CSIC colleagues (external to EuroSea) on Ecosystem Based Fisheries Management, which requires a massive amount of environmental information to explain key mechanisms and drivers of fish population dynamics. Several programmes, such as the European Union's Copernicus Marine Service, greatly improve data availability and promote the use of several products to support Blue Economy activities, such as fisheries. The work assessed the environmental link between the north-west Mediterranean dynamics and a key population process, i.e., recruitment, of a highly valuable demersal resource for the local fishing sector, the European hake. Two hake stocks were analysed comprising the Geographical Subareas (GSA) 5 and 6 defined by the General Fisheries Commission for the Mediterranean. These areas present contrasting oceanographic features representing oligotrophic waters (GSA5) and more productive waters with riverine influence (GSA6). Deep water formation during winter in the Gulf of Lion is also a key phenomenon explaining the response of the hydrology and production in the north-western Mediterranean.

In order to assess the environmental-population link, several Copernicus Marine Service products were used, mainly from satellite observations (Sea Surface Temperature and chlorophyll-a) and physical modelling reanalysis, both specific to the Mediterranean. Using Generalised Additive Models to compute the relationships with the environment and with the Spawning Stock Biomass (SSB), the task team showed that recruitment in GSA5 could be captured by winter SST and SSB (% explained deviance=52). In GSA6, recruitment can be modelled using yearly averaged SST, chorophyll-a, water column salinity and SSB (%

[83] https://www.mdpi.com/2071-1050/14/15/9211

explained deviance=79). In the face of climate change this information is crucial for projecting stock scenarios using climate modelling and stock exploitation intensity with the ultimate goal of reaching sustainable levels of the stocks in question. The work described above was presented at the ICES Annual Science Meeting, Bilbao, Spain, 11-14 September 2023 (Poster: Disentangling the environmental forcing of the European Hake stocks (Merluccius merluccius) (Linnaeus, 1758) in the Western Mediterranean).

Task 6.3: Multipurpose integration of BOOS & HELCOM observing networks

Task leader: DMI, Partners: TalTech, Co-developers: HELCOM, BOOS

This task produced two deliverables during this reporting period: 1) Deliverable D6.2 "Demonstration of annual/quarterly assessments and description of the production system" was submitted in October 2022. This report summarises the EuroSea efforts on integrating observations from both the BOOS and HELCOM monitoring networks, with reanalysis production tool developed in CMEMS, resulting in a more fit-for-purpose operational oceanography system and enhanced environmental assessments in the Baltic Sea. 2) Deliverable D6.6 "Assessment of the benefits of the BOOS-HELCOM integrated system and recommendations for transfer this to other sea areas" was submitted in October 2023. This report summarises the demonstrated benefit of integrating BOOS and HELCOM observations with CMEMS observations, including a) improved observation data accessibility by BOOS, CMEMS INSTAC and EMODnet, b) improved quality of frequently updated CMEMS reanalysis, and 3) improved quality and update frequency of eutrophication assessment in the Baltic Sea based on the reanalysis.

Work carried out in this period included: 1) Assimilating frequently updated ship data from BOOS and HELCOM members, together with CMEMS observations, to generate a new reanalysis for the period of 2020-2021; 2) Validating the quality of the new reanalysis and intercomparing with existing CMEMS interim reanalysis, showing improved quality; 3) Performing eutrophication assessment based on HELCOM method and standards, by using different reanalysis products, 4) Performing a preliminary validation of the indicators derived from DMI reanalysis and CMEMS reanalysis. Furthermore, 5) the ship CTD dataset for 2022 was collected and updated from BOOS members, CMEMS INSTAC, ICES and EMODnet, 6) a new interim reanalysis for year 2022 was carried out by DMI with assimilating the frequently updated new T/S profile dataset, and results were validated, 7) the new T/S profile dataset was shared with CMEMS BALMFC production unit and used by BALMFC to generate a new CMEMS interim reanalysis, and the results were validated showing improvements from previous CMEMS interim reanalysis, 8) the DMI new reanalysis in 2022 and new CMEMS BALMFC reanalysis thus have similar quality and they were both used to generate eutrophication assessment by Taltech, 9) the quality of the reanalysis-based assessment was compared with observation-based assessment, showing agreement in most of the sub-basin areas, and 10) the benefit of BOOS-HELCOM-CMEMS integration was assessed and recommendations were made.

Generally, the products were designed in close consultation with the HELCOM community and introduced at relevant HELCOM meetings. The developed products on extremes and environmental state were presented at the HELCOM State & Conservation WG meeting on 9-12 May 2022, with a request to get feedback from the contracting parties by 6 June 2022. A workshop on "Full value chain integration for monitoring and assessment" was organised as a side event of the 10th EuroGOOS International Conference, with participants representing EuroGOOS, regional operational oceanography systems (BOOS, NOOS, IBIROOS, MONGOOS and ArcticROOS), ICES Working Groups, HELCOM, EMODnet-Physics, CMEMS INSTAC Baltic, BALMFC, national monitoring agencies and EPA. The feasibility for extending to other regional seas, other environmental indicators and fishery advice applications, were recommended by the workshop participants. The details of these feasibility assessments and recommendations can be found in the workshop report. The work in this

period was presented at different meetings: 1) BOOS Scientific Workshop, Helsinki, May 2023 (oral presentation: Samlas O. Potential of CMEMS products for assessing eutrophication status of the Baltic Sea sub-basins); 2) the 10th EuroGOOS conference, Galway, 2-5 October 2023 (Samlas O. Potential of CMEMS products for assessing eutrophication status of the Baltic Sea sub-basins); 3) EuroSea Workshop "Full value chain integration for monitoring and assessment", Galway, 5 October 2023 (Oral presentation: Linders J.: NRT CTD data flow from ship further to BOOS, Copernicus and EMODnet via automatic QC; She J.: Full value-chain integration and its impact on reanalysis; Lips U. Eutrophication assessment and validation). The workshop report has been disseminated to DG-MARE, EMODnet and CMEMS (MOi).

Task 6.4: System Operation

Task leader: Xylem, Partners: CSIC, MI, Co-developers: MOWI, AVRAMAR

Two data buoys were deployed in 2022. In Ireland, a buoy was deployed measuring currents and winds and air pressure, as well as pH, conductivity, oxygen, temperature and total algae at the Deenish Island salmon farm facility (MOWI) in southwest Ireland. Data from the buoy were delivered to a local display solution as well as ingested in the Copernicus Marine Service In Situ TAC with the help from WP6.1. Training of local personnel was carried out in connection to the deployment. The platform was deployed in Ireland by the Deenish Island aquaculture farm owned by stakeholder MOWI[84]. MOWI had participated in the determination of the requirements and several solutions had been evaluated in the discovery phase of the product. The team landed on a design that incorporated an autonomous buoy powered by solar power and transmitting data real time to users. The buoy experienced heavy currents in the summer of 2022, and was dragged under. Some of the equipment inside the buoy, particularly the data logger and the communication equipment failed and the buoy was therefore recovered. Rebuilding the buoy started immediately. The EuroSea data buoy was redeployed in October 2023 with crews from Xylem in the UK and in Norway spending two days on site doing training, preparing the buoy and then deploying it back in a slightly different location by Deenish island.

A second buoy was deployed by AVRAMAR facilities at the El Campello site close to Alicante in Spain. It measures water currents, waves, winds, oxygen, temperature, salinity, chlorophyll and turbidity. Data from this buoy are currently flowing to a central server and visible locally, and work is underway to integrate a dataflow with the Copernicus Marine Service In Situ TAC database. The deployment was assisted by our local subsidiary Sidmar in Spain.

In summary, Task 6.4 achieved milestone MS22 by deploying the first prototype as a pilot to demonstrate the design of a platform to supply stakeholders with data on EOV and marine events that can impact their operations. The pilot consisted of a data buoy and sensors with data flowing to a cloud server and to the stakeholders in real-time. Stakeholder representatives were also trained to maintain and utilise the data from the pilot installation including regular calibration checks.

Deliverable D6.7 "Real-time data to central server with display to stakeholders" was achieved in connection to MS22. D6.7 completes the deliverable from Xylem with dataflows set up to servers available for stakeholders. EuroSea partners in this activity also contributed to the WP6 "Sustainability and Business Plan" and "EuroSea Business Plan" Reports (D6.5 and D8.8).

[84] https://mowi.com/

Cooperation and interaction with other EuroSea WPs

Co-operator	WP activities
WP8	• Participation in the EuroSea Job Profiles Brochure (2022) • Co-writing of news item on website and Twitter: EuroSea's Oceanographic Data Buoys: Navigating Ocean Monitoring for Sustainable Aquaculture (August 2023) • Collaboration in design of KER roll-up for EuroSea final conference (September 2023) • Provided input to the WP8 EuroSea Impact Monitoring Protocol (September 2023)
WP4/7	• Collaboration on Seasonal Forecasting for the Aquaculture Industry (March 2023)
WP4	• WP6 marine observatory for aquaculture includes a link to outputs from WP4 seasonal forecast (related to temperature) in The Copernicus Climate Change Service (C3S) • WP4-5-6-7 cross-cutting meeting (December 2022) • Ocean Decade Co-Design Workshop: Ocean Observing Co-Design exemplar group on Marine Heat Wave, 7-9 June 2022 (Presentation, chair of session, interactive discussions etc.)
WP2	• Strong collaboration between WP6 and WP2 was established through the building of synergies around marine heat waves. A EuroSea MHW task team was created, a MHW workshop organised at the EuroSea annual meeting in May 2022 and a manuscript submitted in September 2022 by WP2 (Dayan et al., 2022). Finally, several members of WP6 and WP2 contributed to the MHW exemplar of Ocean Observing Co-Design programme, one of the three Global Ocean Observing System Ocean Decade Programmes. • WP6 continued to work with WP2 on EOVs and development of indicators
WP1	• WP6 partners participated in the Ocean Practices: OBPS Workshop VI, 5 - 19 October, 2022 (Presentations and Discussion) and together submitted a manuscript (September 2023) for peer-review to the Frontiers in Marine Science special issue Best Practices in Ocean Observing.

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
ClimFish	• Provided information on MHWs to fisheries scientists in a national project called "ClimFish" which is investigating impacts of climate change on Irish fish stocks (T6.1, T6.2 and T6.3).
ICES WGOH	• Provided information on MHWs to the International Council for the Exploration of the Sea Working Group on Oceanic Hydrography (ICES WGOH)
HELCOM, BOOS	• Provided updates on indicator development and model outputs from T6.3
FishClim	• Collaboration in fisheries task 6.2 with presentation at the ICES ASC in September 2023 (see task description)

Achieved main results

Deliverables		
6.1	Connections between Extreme Marine Events and Biological EOVs	✓

6.2	Demonstration of annual/quarterly assessments and description of the production system	✓
6.3	Best Practice on creating “Extreme Marine Events” Hazard maps & forecasts Report	✓
6.4	Linking oceanographic products to fisheries advice	✓
6.5	Sustainability and Business Plan Report	✓
6.6	Assessment of the benefits of the BOOS-HELCOM integrated system and recommendations for transfer this to other sea areas	✓
6.7	Real-time data to central server	✓
Milestones		
MS22	Prototype available for validation	✓
MS25	"Extreme Marine Events" Hazard maps & forecasts - Website	✓
MS29	End-user satisfaction ratings reported	✓
Internal Milestones		
iMS47	CMEMS products are first considered for WGHANSA advice	✓
iMS50	CMEMS products are incorporated into the WGHANSA yearly report	✓

WP7 – Ocean Climate Indicators

Lead: MOI, CO-lead: IO PAN

Objectives
• Generate a feedback loop between EuroSea, climate and ocean services, the economy sector, and decision makers by co-examining ocean climate indicators, assessing their uncertainties and quantifying their economic value
• Provide user-relevant products for ocean climate monitoring and deliver ocean forecasting indicators in support of improved ecosystem management, risk management and blue growth
• Carry out AtlantOS (H2020)[85] recommendations for observing system strategies, and demonstrate the improvements though ocean climate indicator developments with decreased uncertainty

Summary of progress towards WP objectives

WP7 addresses innovative ways to assess the role of the oceans and seas in the Earth's climate through the development, evaluation – including uncertainties - and dissemination of ocean climate indicators and their value for the three pillars of sustainable development: economy (e.g. blue economy), societal (e.g. policy) and environmental sectors (e.g. climate science).

Task 7.0 includes the internal coordination of WP7, providing and exploiting interfaces between WP7 tasks and other EuroSea WPs. The WP7 leaders have ensured that the planned work is carried out according to plan and budget and that the deliverables are produced and milestones are attained on time. The leaders have ensured the establishment of the link with EuroSea project coordination and that the decisions taken at the SC level are implemented. This also includes management of risk registers and assistance with the development of mitigation measures. Support of the coordination to the final EuroSea meeting have been organized at task 7.0 level to assure the contribution to the different meeting session while presenting the results of the 3 tasks, as well as to support the high-level event where results of WP7 have been highlighted during a keynote presentation.

Task 7.1. has evaluated observing strategies and data products needed to determine the economic value of the (variable) ocean carbon sink of European relevant deep convection regions. The analysis is based on operational carbon assessments using a combined observing and modelling approach. Early in this reporting period, the assessment of existing air-sea CO_2 and interior ocean carbon storage data products, methodological approaches and the data flows were investigated. Regional high-resolution model simulations of partners were used to test different observational network strategies in the Mediterranean Sea and Labrador Sea. Techniques to estimate the time integrated ocean uptake of excess carbon (C_{ant}) using different parameter combinations and observation platforms were investigated. Later on, different approaches to value the ocean sink have been demonstrated, comparing a climate-change damage-based approach with an abatement, market-based approach. A high-resolution carbon flux dataset (0.25x0.25 degree) to estimate the ocean carbon sink and source in coastal areas has been used for this purpose. By breaking down the carbon sink by nations EEZ, this task estimated which countries are the largest donors of ocean carbon wealth and which countries would be affected the most if a weakening of the ocean sink would need to be compensated by higher emission reduction levels. Moreover, ocean carbon variability in the

[85] https://www.atlantos-h2020.eu/

interior ocean has been investigated in order to assess the linkage of these processes for the use in national climate action (NCA) plans delivered in the framework of the Paris Agreement. In summary, large-scale connectivity in the ocean does not allow clear delineation of patterns of regional carbon uptake across national boundaries, limiting an assessment of the Exclusive Economic Zones (EEZ) in light of NCA plans. A major recommendation from this task is the improvement of carbon sampling in all nations EEZ regions and following global standards and under FAIR principles.

WP7.2 has published an analysis of societally-relevant predictions of ocean variables and indicators in seasonal forecast systems and has achieved advancements with respect to stakeholder engagement activities. A particular emphasize of the workflow was linked to the indicators describing MHWs, and this task has contributed to unravel approaches for improved prediction skills of marine extremes, leveraging the role of subsurface ocean change to establish a more comprehensive description of these specific changes in the ocean of high socio-economic relevance. These results have been further supported by outcomes on characteristics of MHWs at EEZ level, further enhancing the recommendation for strengthening surface and subsurface observing systems in most national waters to better establish local-scale risk assessments and to respond to diverse stakeholder needs.

WP7.3 has its focus on exploring opportunities to further strengthen observing system capacities through optimization tests, including for improved quality control approaches. Particularly, the work had been focused on upscaling the spatio-temporal coverage and quality of carbon flux estimates over the tropical Atlantic. This is being achieved through a Tropical Atlantic Observing System (TAOS) optimization demonstration using an integrative multi-platform approach. The task proceeded while closing observational gaps through an integrative multi-platform approach, bringing together the different strengths from combining various observation techniques. As large amounts of field work had been included, this task has been significantly affected by the pandemic, but a major part could be compensated through successful external additional funding for the ASV mission following the withdrawal of an external partner. Moreover, a consistent and rigorous correction procedure to quality-control and process of the data from the integrated multi-platform approach has been implemented. In addition, the data have been used to apply a neural network approach, and the results emphasize the need for high-quality homogeneously calibrated carbonate variable measurements, which have been demonstrated to be mandatory for computing air-sea CO_2 fluxes at a basin scale from multiple observing platforms.

Detailed progress per task (or subtasks)

Task 7.0: Coordination

Task leader: MOI, Partners: IO PAN

Coordinators of WP7 have maintained internal communication pathways for the successful delivery of WP7 in EuroSea, including the living online document, and archive and document exchange platform. Regular WP7 meetings have been continued, which allowed each task to provide an overview on current advancements, and to raise and alert on challenges affecting the progress of the work, and provided the opportunity to all WP members and partners to exchange on specific aspects, and raise new opportunities. As with other WP coordination activities, logistics and content preparation as well as moderating the meeting and synthesizing relevant outcomes was led by WP co-leads. Beside the WP-wide exchanges, further dialogues had been established at task levels, particularly with the task leadership, and the PIs on upcoming deliverables. An example includes the co-constructed development of the new stakeholder engagement activity of task 7.2,

which could be also brought forward for input at EuroSea SC level through the task 7.0 coordination team. Moreover, there was continued support from task 7.0 provided to best support the development of all deliverables, including dedicated online meetings, writing sessions, and revision processes. Coordinators have participated regularly to all SC meetings, conveyed any relevant and actionable information from SC discussions to WP members assuring project-wide dissemination of relevant matters. Coordinators, as members of the EuroSea SC, took part in shaping the delivery process related to project-wide issues like stakeholders' engagement, project impact description, outreach and communication delivery and other as requested by the project coordination. Coordinators solicitated WP-wide input to the EuroSea annual meetings. They also took the stage, or coordinated the contributions from task leaders at these events to present the synthesized input and respond to any questions from internal and external project partners. Coordinators solicitated WP-wide input to the EuroSea Final Meeting and the high-level symposium. Task 7.0 also participated in the EuroSea stakeholder team for further training and support. Coordinators assisted with specifying cross-WP activities aimed at consolidating project's delivery as well as strengthening the impact of WP7 actions. Meetings with WP4 mutually benefited both groups and resulted in an establishment of a more consistent value-chain from observations to information product development. Specifically, the developments of deliverables D7.5 and D7.6 have been extensively supported during the entire development process.

Task 7.1: Carbon audit of the European relevant deep convection regions

Task leader: GEOMAR, IfW, Partners: Euro-Argo Eric, CNRS, Ifremer, DAL, MUN, MOI

Currently, the ocean carbon sink annually removes about a third of anthropogenic fossil fuel and industrial CO_2 emissions, reducing therefore climate change damages and CO_2 abatement costs. While the land sinks have entered climate policies, the ocean sink has not - for good reasons since the former stores carbon within the boundaries of a state while the ocean removes carbon from the atmosphere rather in its property as a global common. However, the question remains what is the value of the ocean carbon sink and should it be differently attributed when comparing a coastal state with a large exclusive economic zone (EEZ) compared to landlocked state. However, in order to estimate blue carbon at the EEZ level, its variability and advection has to be understood to allow for any delineation of patterns of regional carbon uptake across national boundaries, limiting an assessment of the Exclusive Economic Zones (EEZ). In this task, key approaches for the assessment of the global ocean carbon uptake have been applied to ocean areas. The observational requirements for applying statistical approaches (i.e., artificial neural networks, Fourrier et al., 2020) to reconstruct dissolved inorganic carbon (DIC) from oxygen, nutrient and hydrographic data are analysed. It is shown that even small changes in the DIC content determined in this way can be linked to anthropogenic increases in atmospheric carbon (C_{ant}). Furthermore, it has been shown that multilinear regression techniques can be used to produce maps of ocean surface carbon fluxes at very high spatial resolution, which in turn can provide a much more accurate estimate of regional CO_2 uptake (or release). Finally, a quantification of the redistribution of dissolved gases in boundary current systems could be investigated by following recommendations for observational methods stemming from this deliverable.

Further, different approaches to value the ocean sink have been demonstrated, comparing a climate-change damage-based approach with an abatement, market-based approach. A high-resolution carbon flux dataset (0.25x0.25 degree) has been used to estimate the ocean carbon sink and source in coastal areas. A net sink of 1.72 GtC proportional to countries with negative carbon fluxes in their EEZ had been assigned. Annual value of the global ocean sink have shown to range from 61.19 B USD (Std 31.80), equivalent to the 2021 GDP of Slovenia, to 1433 B USD (Std 94.30), equivalent to the 2021 GDP of Spain (World Bank data) for the

abatement cost-based assessment approach (assuming full emission trading and low ambition levels in the national determined contribution) and for the climate-change damage-based assessment approach relying on an upper value of the social cost of carbon in our investigation. By breaking down the carbon sink by nations EEZ this task estimated which countries are the largest donors of ocean carbon wealth and which countries would be affected the most if a weakening of the ocean sink would need to be compensated by higher emission reduction levels.

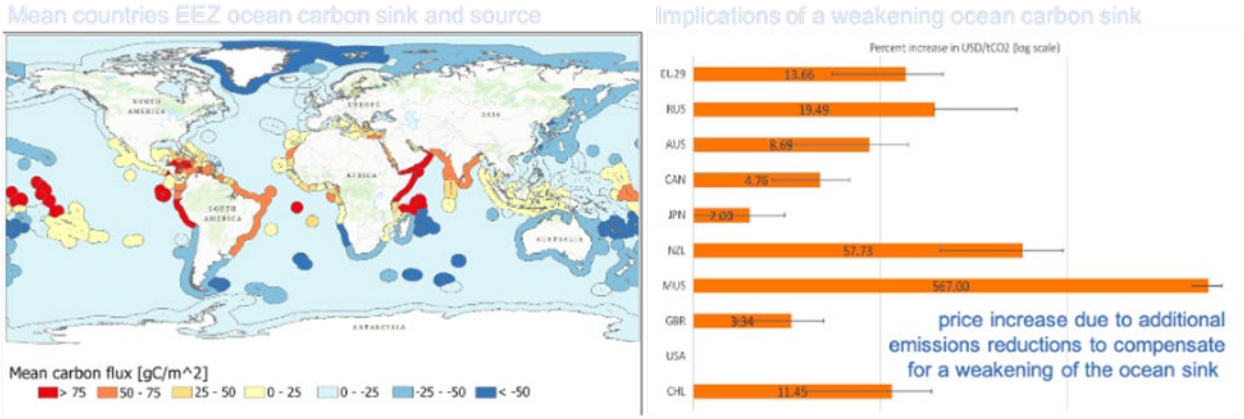

Figure 9. Left panel: Mean countries EEZ ocean carbon flux (sink and source); Right Panel: Implications of Weakening of Ocean Sink. The figure shows the price increase due to additional emissions reductions to compensate for a weakening of the ocean sink by about 12 percent for the NDCs with high emissions reduction ambition. The figure shows the 10 countries with largest price increase. The abbreviations represent VUT: Vanuatu, SLB: Solomon Islands, FJI: Fiji, MUS: Mauritius, TON: Tonga, MDG: Madagascar, WSM: Samoa, NAM: Namibia, NZL: New Zealand, and GNB: Guinea-Bissau. From Rickels et al., 2023, EuroSea deliverable D7.5

This results if this task reveals strong recommendations, i.e. the improvement of carbon sampling in the ocean in all nations EEZ regions following global standards and FAIR data principles. A need for defining responsibilities for such global integration and the resourcing is required. It is recommended to make use of statistical methods to create surface and interior carbon parameter distributions via multiparameter approaches with a sufficient amount of reference data (e.g., co-located DIC, oxygen, nutrients, chlorophyll-a, hydrography). In the light of the ongoing crisis related to global availability of the Certified Reference Materials (CRMs) for carbonate system measurements, provision of European-produced material becomes critical to enable traceability of future measurements. Nations should be encouraged to provide appropriate resources by means of corresponding European directives. Example for such national commitments is the collection of reference data in the framework of the Common Fisheries Policy[86].

In June 2023, the last EuroSea deep Argo float was deployed in the North Atlantic during BOCATS-OVIDE cruise, to replace the float that failed almost right after its launch at the start of the project. It was deployed together with 4 other Deep floats from Argo-France to contribute to the observation of water mass property changes, circulation, and acidification in the North Atlantic subpolar gyre. The float had been tested by Euro-Argo ERIC beforehand in early 2023 in Ifremer hyperbaric chamber and pool, to ensure its proper functioning. As the other EuroSea floats, they are equipped with an oxygen sensor that will bring new data to improve methods to monitor the uptake and storage of carbon in the Irminger Sea (Asselot et al. 2023) and its propagation within the deep circulation.

[86] https://oceans-and-fisheries.ec.europa.eu/policy/common-fisheries-policy-cfp_en

Task 7.2: Demonstrate societal benefit of physical Ocean Monitoring and Forecasting Systems: Design of user driven products

Task leaders: CMCC, ECMWF, Partner: MOI

Ocean indicators are a powerful tool to bridge the knowledge transfer at the science-policy nexus, and to deliver reliable tools for socioeconomic use. Due to their increase in intensity and frequency from climate change, indicators which allow for monitoring marine extremes such as marine heatwaves are then of vital interest. This task has not only developed new methods for indicator evaluations, such as a new classification for indicator stages (climate, complex and user-defined indicators), but also investigated the socioeconomic relevance of ocean indicators. Particularly for the latter and based on a new stakeholder strategy, methods for forecasting ocean indicators have been demonstrated and implemented for the first time. The focus had been provided on MHWs. For example, a dedicated study had been performed on unravelling characteristics of MHWs at country's EEZ waters to contribute to decision support for management and adaptation at national scale (Dayan et al., 2022[87]). Particularly, the variability of surface and subsurface MHWs is assessed over the 1987-2019 period in the Mediterranean EEZs. Results highlight the important differences between surface and subsurface extreme events: the frequency of MHWs is higher at the surface than in the subsurface and has significantly increased in most EEZs both at the surface and in the subsurface over the study period, while MHW duration is longer in the subsurface than at the surface in all EEZs. The intensities of MHWs decrease at depth, while its increase over time is more disparate throughout the basin. A choice of a "Top-Ten" list of EEZs shows that the impact to EEZs is different depending on the marine heatwave characteristics and the depth, emphasizing the need to consider all characteristics and to avoid focusing only on the ocean surface.

Moreover, seasonal prediction of MHWs has been developed (McAdam et al., 2023[88]). As MHWs damage marine ecosystems and services, with effects identified mostly below the ocean surface, it is necessary to create a truly user-relevant detection system, i.e., to provide subsurface forecasts of MHWs. Task 7.2 has demonstrated the feasibility of seasonal forecasting of subsurface marine heatwaves by using upper ocean heat content. Surface and subsurface event forecasts have been validated by an operational dynamical seasonal forecasting system against satellite observations and an ocean reanalysis, respectively Figure 14). Results have shown that indicators of summer events (number of days, strongest intensity, and number of events) are predicted with greater skill than surface equivalents across much of the global ocean. The study also identified regions which do not display significant surface skill but could still benefit from accurate subsurface early warning tools (e.g., the mid-latitudes). Overall, the results highlight the necessity of strengthening surface and subsurface observing systems in most national waters to better establish local-scale risk assessments and to respond to diverse stakeholder needs.

[87] https://www.frontiersin.org/articles/10.3389/fmars.2023.1045138/full
[88] https://www.nature.com/articles/s43247-023-00892-5

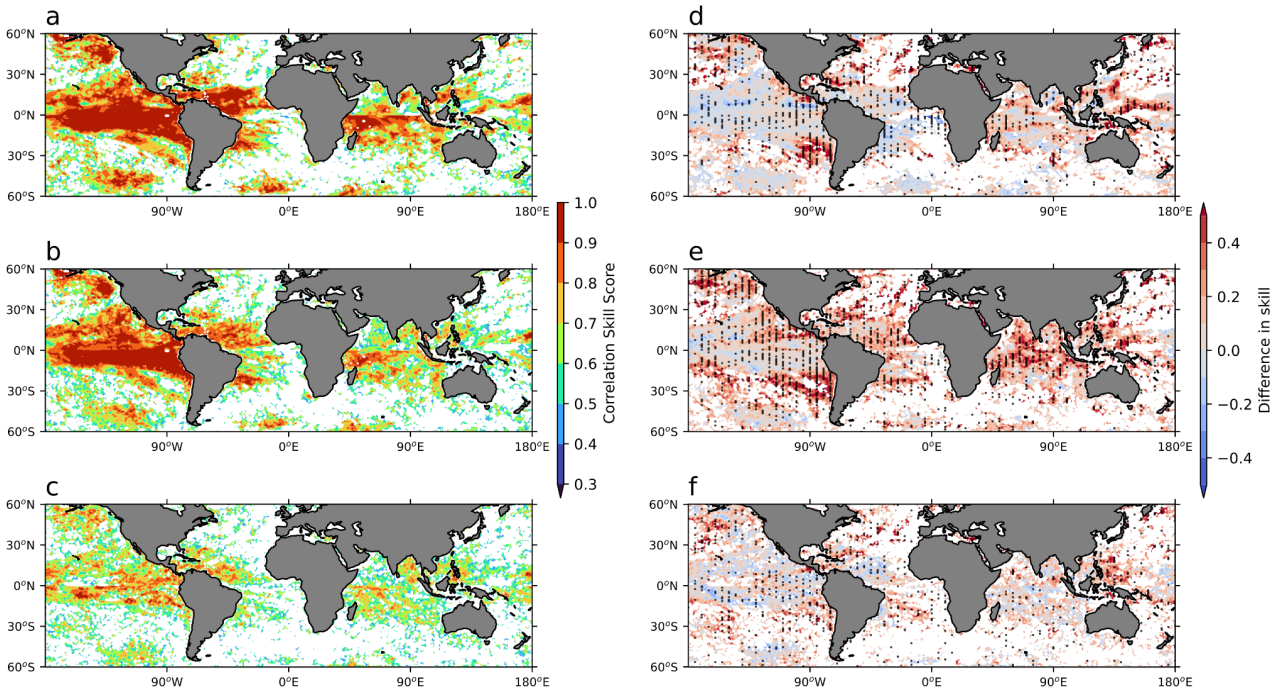

Figure 10. Correlation skill score of subsurface MHW indicators for (a) number of MHW days, (b) strongest Intensity, (c) number of events. Difference between subsurface and surface MHW indicator skill (d) number of MHW days, (e) strongest Intensity, and (f) number of events. Positive values in (d–f) represent improvement in subsurface event detection over surface event detection. All scores correspond to the hemisphere-specific summer season and the 1993–2016 period. Regions in which skill scores in both models are insignificant are masked out (white). Black stippling indicates statistically significant differences in correlation (d–f).

The task team concluded its work by sharing the result of their work in the final deliverable of this task: Deliverable D7.4 (Skills of user-relevant indicators).

Task 7.3: Quality enhancement of tropical carbon fluxes through network optimization of the Tropical Atlantic Observing System

Task leader: GEOMAR, SU, Partners: Euro-Argo Eric, IRD, UERJ, UFPE

Most of the field surveys of task 7.3 were conducted in the previous reporting period, such as the year-long mission with an ASV (Saildrone) in the tropical Atlantic to measure air-sea gas fluxes of CO_2 as well as mooring installations (Brazilian PIRATA and at CVOO). The remaining field work was finished in this reporting period and data analysis and synthesis continued. Only the installation of a CO_2 sensor on the Brazilian PIRATA mooring failed because of a technical malfunction of the sensor. During the reporting period a Wave Glider and a VeGAS pCO2 sensor were recovered on 23 May 2022. It can be pointed out that technical sensor installation, deployment, and recovery of these autonomous platforms were well performed. Thus, thanks to these VeGAS pCO2 sensor deployments, this task also explored the possibility of integrating this device into existing PIRATA platforms of the TAOS. Due to the pandemic, the purchase of the pCO2 sensor for the Brazilian PIRATA mooring had been delayed. Leadtime for the sensor increased, resulting with its availability only late 2021 at manufacturer premises. Meanwhile, the Brazilian PIRATA cruise service at 8°N-38°W was delayed during more than 2 years. After successful tests in lab in spring 2022, the sensor was deemed ready for deployment. Unfortunately, during the June 2022 cruise there was malfunctioning and misconnection issues with the sensor, and it could not be deployed, despite huge efforts spent by scientists and engineers,

and interaction with the manufacturer. The sensor had to come back for maintenance to the manufacturer. The current goal is now to be able to deploy the CARIOCA instrument in one PIRATA mooring as soon as possible, in order to complement the existing measurements at 0-10°W and 6°S-10°W.

Nevertheless, thanks to the multi-platform strategy followed in EuroSea project and in the studied region and to the successful deployment of numerous and diverse carbon-observing platforms, this task has demonstrated the technical feasibility to obtain high-quality observations for air-sea CO_2 fluxes in an under-sampled and remote region in the Atlantic, but also the capacity to address quality-control processes based on numerous monitoring tools (see deliverable D7.1 and D7.2). Thus, the optimization of the existing TAOS has been well initiated and the capacity to address different elements for monitoring tropical carbon variations has increased.

To better constrain changes in the ocean's capture and sequestration of CO_2 emitted by human activities, in situ measurements are needed. Tropical regions are considered to be mostly sources of CO_2 to the atmosphere due to specific circulation features, with large interannual variability mainly controlled by physical drivers (Padin et al., 2010). The tropical Atlantic is the second largest source, after the tropical Pacific, of CO2 to the atmosphere (Landschützer et al., 2014). However, it is not a homogeneous zone, as it is affected by many physical and biogeochemical processes that vary on many time scales and affect surrounding areas (Foltz et al., 2019). The TAOS has progressed substantially over the past two decades. Still, many challenges and uncertainties remain to require further studies into the area's role in terms of carbon fluxes (Foltz et al., 2019). Monitoring and sustained observations of surface oceanic CO_2 are critical for understanding the fate of CO_2 as it penetrates the ocean and during its sequestration at depth. This task is dedicated to optimize demonstration using an integrative multi-platform approach and to complement with a neural network approach in the tropical Atlantic. The work relies on different observing platforms deployed specifically as part of the EuroSea project (a Saildrone, and 5 pH-equipped BGC-Argo floats) as well as on the platforms as part of the TAOS (CO_2-equipped moorings, cruises, models, and data products). Most recent advancements build on the work done in earlier deliverables, which tackle the deployment and quality control of pH-equipped BGC-Argo floats and Saildrone data. The combination of multi-platform observations, models, and neural network techniques has been used to assess our ability to derive air-sea CO_2 fluxes in the tropical Atlantic over the period 2018-2021. Results show that overall, the tropical Atlantic is a source of CO_2 to the atmosphere with high variability (seasonal and interannual) in the study area, consistent with the literature. Although significant advancement could be made, there is still a great need for sustained observations, either by using vessels of opportunity that provide regular high-quality monitoring of specific areas (such as the France-Brazil SOOP line) or by developing specific pilot observation experiments such as the one implemented in EuroSea. Indeed, a Saildrone, BGC-Argo floats equipped with pH sensors have been deployed and collocated matchups between these platforms, moorings, and cruises have been carried out. It is also important to emphasize that there is only one CO_2 mooring left in the area (part of the PIRATA network). It is difficult to maintain long-term datasets due to harsh conditions, sensor problems, and piracy. In addition, there is a need to further improve the ability of platforms to accurately measure the variables needed to estimate CO_2 fluxes (e.g. acoustic wind measurements on Argo floats). It is also necessary to continue to improve sensor technology to provide reliable measurements over the long term. This, combined with a good observation strategy and QC algorithm procedures, will allow us to improve CO_2 products. Saildrone platforms provide high-quality data and have the advantage of onboard collocated measurements of wind speed and atmospheric CO_2 needed to derive air-sea CO_2 fluxes. However, this high-frequency dataset is not the most cost-effective and we should not rely solely on these types of platforms to study entire ocean basins. Including further biogeochemical Argo floats in this approach will hold promising results in the future.

Saildrone platforms can be used, as it has been done in EuroSea (matchups with Argo floats and moorings), as a tool to link platforms. Neural networks allow gaps to be filled and provide CO_2 estimates by enhancing limited T/S/O_2 datasets with given uncertainties. When used in combination with pH sensors mounted on BGC-Argo floats, they help derive pCO_2 with reduced uncertainties.

Overall the results suggest that an effective and economical way to monitor the area and ensure comparisons between platforms, as well as providing the accurate dataset needed to improve neural network training and prediction, could be pilot studies with permanent 'rendezvous' between different monitoring platforms. In addition, an OSSE including in situ errors would explicitly help to define where to use the different observation platforms (Saildrone, BGC Argo floats, moorings) to best improve our coverage of the oceanic pCO2 system.

Cooperation and interaction with other EuroSea WPs

Co-operator	WP activities
WP 2,4,6	• MHW working group which includes activities on seasonal forecasting, inter-dataset comparisons, definition of common user-relevant indicators. There are various regional focus groups (Irish Sea, Baltic Sea, Mediterranean Sea etc).
WP4	• Sharing of information, data and climate indices for seasonal forecasts systems and validation datasets. • Ocean Decade Co-Design Workshop: Ocean Observing Co-Design exemplar group on Marine Heat Wave, 7-9 June 2022
WP4,5,6	• WP4, 5,6,7 cross-cutting meeting (December 2022)
WP4/6	• Collaboration on Seasonal Forecasting for the Aquaculture Industry (March 2023)

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
MedPan MPA network	• Promote the co-design of user oriented seasonal indicators
ISPRA (Italian Institute for Environmental Protection and Research)	• Promote the co-design of user oriented seasonal indicators
EEA	• Promote the use of CMEMS ocean indicators
PIRATA/TAOS	• Presentation of T7.3 achievements and discussions on augmentation of PIRATA platforms by carbon observations in the future

Achieved main results

Deliverables		
D7.1	Report on demo mission and dissemination pathways of obtained data	✓
D7.2	Development of BGCArgo data quality validation based on an integrative multiplatform approach	✓
D7.3	Estimate of magnitude and drivers of regional carbon variability for both regions	✓

D7.4	Skills of user-relevant indicators	✓
D7.5	Economic benefit of regional ocean carbon uptake	✓
D7.6	Integration of in situ and satellite multi-platform data [estimation of carbon flux for trop. Atlantic	✓
Milestones		
MS9	Deployment of BGC- Argo and PIRATA CO2 sensor in trop. Atlantic	✓
MS18	Accomplished ASV mission in TAOS environment	✓
MS27	Implementation of results into the CMEMS Ocean State Report	✓

WP8 - Communication: Engagement, Dissemination, Exploitation, and Legacy

Lead: EuroGOOS, CO-lead: GEOMAR

Objectives
• Deliver professional communications, stakeholder engagement and business exploitation support to the project and its demonstrators
• Enhance collaborative, inclusive, and strategic stakeholder dialogue that moves beyond stakeholder consultation towards co-design
• Enable exploitation of the project's results and products in business sector, sustainable strategic partnerships and governance, as well as strategic foresight
• Provide tangible support and guidelines on intellectual property rights and business development along the Responsible Research and Innovation principles and best practice in knowledge and technology transfer
• Support capacity building to empower strategic partnerships, support business development and communicate achievements effectively
• Ensure the project's legacy is sustained with consolidated contributions to short, medium and long-term project's goals

Summary of progress towards WP objectives

From May 2022 to October 2022, WP8 engaged stakeholders across policy, academia, industry, and the public, aligning with its Communication Plan (D8.1). Key engagements included the workshop at European Maritime Day 2022[89], the "Ocean Best Practices Workshop VI – A virtual Global Meeting[90]", the 3rd Annual meeting [91]in May 2022 with the involvement of SEA-EU [92]students, and the International Conference for Young Marine researchers in September 2022. Notably, the EuroSea Exhibition[93] (MS20) was launched in July 2022, translated to English, Spanish, and Catalan and reached diverse audiences in events like the European Researcher's Night 2022 in both Spain and Germany. Lessons from these engagements were encapsulated in reports, notably D8.3 "Lessons Learned on Science-Policy Interface".

WP8 continued to promote its activities over X (Twitter)[94], YouTube[95], and the EuroSea website[96]. WP8 collaborated with the EuroSea Innovation and Stakeholder Committee (ISC) to receive feedback on the EuroSea exploitation activities and the level of innovation in the project. Four EuroSea innovations from WP5 and WP6 were highlighted on the Innovation Radar platform[97] such as the OSPAC software which was presented at the Sustainable Ocean Summit 2022 in Barcelona. Furthermore, a Report on economic value of

[89] https://eurosea.eu/new/join-our-european-maritime-day-workshop-ocean-observations-marine-data-and-services-for-the-european-green-deal/
[90] https://www.oceanbestpractices.org/community-engagement/workshops/ocean-practices-obps-workshop-vi/
[91] https://eurosea.eu/new/4537/
[92] https://sea-eu.org/
[93] https://eurosea.eu/download/eurosea-exhibition-brochure-2023/?wpdmdl=5238&refresh=653680ac9a9a51698070700
[94] https://twitter.com/Euro_Sea
[95] https://www.youtube.com/@EuroSeaH
[96] https://eurosea.eu/
[97] https://innovation-radar.ec.europa.eu/

ocean observations (Deliverable D8.6) was submitted in October 2022, underscoring their value with strong commercial viability as identified in the Exploitation Strategy.

To ensure the enduring legacy of EuroSea two major activities were pursued: 1) The implementation of an impact monitoring protocol with consistent tracking and reporting mechanisms, and 2) The EuroSea Anniversary webinar to discuss project progression and legacy with stakeholders. In addition, a workshop was conducted at the 3rd Annual Meeting in Cadiz, providing input for D8.3 on Lessons Learned on Science-Policy Interface and the project's website impact pages.

From November 2022 to October 2023, WP8 extensively engaged with diverse stakeholders. Key policy engagement activities included the EuroSea Anniversary Webinar in November 2022, the participation in the European Maritime Day (EMD) 2023 workshop in Brest, the EuroSea Symposium[98] in Paris in September 2023, and support of the EurOCEAN ocean science-policy conference in Vigo in October 2023. Academia engagement highlights included the presentation of the EuroSea itinerant exhibition at CommOCEAN 2022 in France, and contributions to conferences like Oceans 2023, ASLO Aquatic Sciences Meeting 2023 and the 10th EuroGOOS International Conference. Furthermore, EuroSea provided support to the Ocean Observers Initiative[99] by financing the production of educational materials for the field of ocean observation and thus investing in the present and future education of the next generation. To further engage and educate the next generation on ocean observing and forecasting, EuroSea WP8 contributed to an AtlantECO Podcast series, participated in a research cruise with the WASCAL Floating University, and attended a roundtable discussion with students in Berlin, emphasising the significance of sustainable ocean observations for the future. For industry engagement, WP8 actively supported the EuroSea demonstrator work packages in outreach activities. Public engagements included showcasing the EuroSea exhibition at various European events such as the Galway Science & Technology Festival in November 2022, 'Science for all' fair in May 2023, and the Ocean Race Grand Finale[100] in June 2023.

Over this reporting period, EuroSea WP8 amplified its digital dissemination over X (Twitter), YouTube, and the EuroSea website. In addition, dissemination materials, including a comic book featuring EuroSea funded illustrations and engaging ocean career job profiles, were developed to foster a broader understanding of ocean observations, appeal to the next generation and inspire early career ocean professionals. Alongside digital efforts, the WP8 team and EuroSea's project coordinator presented the project at numerous events and raised awareness by showcasing the EuroSea exhibition to diverse audiences. Supplementary materials, such as roll-ups for 4 EuroSea Key Exploitable Results (KERs), were designed for enhanced visibility during in-person events and are available on the EuroSea website.

WP8, building upon the EuroSea Exploitation Strategy (D8.4), submitted the EuroSea Business Plan (D8.8) in June 2023, focussing on the four KERs with highest commercialisation potential. These KERs include the OSPAC software (WP5), a solution for marine sensors to measure and forecast oxygen, heat and pH related Extreme Marine Events onsite for aquaculture (WP6), low maintenance tide gauges (WP5), and a Prototype sea level planning and scenario visualisation tool (WP5).

[98] https://eurosea.eu/new/eurosea-symposium-highlights-the-urgency-of-integrated-ocean-observing-and-forecasting/

[99] https://www.oceanobservers.org/

[100] https://eurosea.eu/new/eurosea-day-during-the-ocean-race-grand-finale-towards-a-user-focused-interdisciplinary-and-responsive-european-ocean-observing-and-forecasting-system/

Throughout this reporting period, regular impact tracking took place through partner reports, discussions, and webinars with policy and academic stakeholders. The results were delivered as impact pages on the EuroSea website. This effort resulted in a comprehensive impact registry of nearly 100 EuroSea impacts. The EuroSea Legacy Report (D8.12), set to release in November 2023, will build on this process to deliver a concise brochure promoting the key impacts and messages of EuroSea. In addition, EuroSea provided recommendations on Responsible Research and Innovation (RRI) in ocean observing (D8.9) on how to increase common responsibility towards the ocean and support its sustainability.

Detailed progress per task (or subtasks)

Task 8.0 Coordination

Task leader: EuroGOOS, Partners: GEOMAR

WP8 supported the consortium and coordinator in the organisation of the EuroSea annual meeting in May 2022 in Cadiz. One WP8 meeting took place during this period to prepare for the WP8 report at the annual meeting.

In this reporting period, four WP8 meetings took place, targeted at the progress review and the preparation of the EuroSea final annual meeting in September 2023 in Paris.

WP8 had again to deal with personnel changes: Due to shortage in personnel, partner RBINS stepped out of their role as leader of task 8.2 (Dissemination). The lead was taken over by WP8 co-leader GEOMAR. The task leader of task 8.3 (Exploitation), exploitation manager and chair of the Innovation and Stakeholder Committee from the Marine Institute, Ireland, also stepped out of WP8 in May 2023. The finalisation of their tasks, however, were still ensured by the Marine Institute and all deliverables were submitted as planned.

To strengthen the engagement and dissemination tasks and WP8 in general, communication specialists from the project partners Euro-Argo ERIC and WMO joined the WP8 team in May 2023. They especially supported tasks related to societal outreach and ocean literacy. In addition, WP8 (through leader EuroGOOS) contracted the innovation consultancy Sapien Innovation to support the finalisation of the IPR management and business exploitation in August 2023.

As in previous reporting periods, training activities on stakeholder engagement, communication, IPR management and business exploitation were organised by this WP8 task. These trainings have contributed to internal capacity building in the EuroSea consortium. In February 2023, WP8 leader EuroGOOS delivered milestone MS28 (Capacity Building Report Card).

Task 8.1: Engagement

Task leader: EuroGOOS, GEOMAR, Partners: SciencEthics, MI, RBINS, ISPRA, SOCIB

WP8 continued active engagement with stakeholders and users according to plans outlined in its Communication Plan (D8.1) - policy, academia, industry, society. Lessons learnt from these activities were documented in deliverables (see task 8.4 Legacy below).

Policy was engaged through several activities. In May 2022, WP8 organised a workshop at the European Maritime Day conference to promote the messages put forward by EuroSea and several other EU projects in the joint policy brief ‘Nourishing Blue Economy and Sharing Ocean Knowledge’. The joint activity with EMODnet and Blue-Cloud delivered perspectives on the “Ocean observations, marine data and services for the European Green Deal”. In October 2022, WP8 released D8.3 “Lessons Learned on Science-Policy

Interface". The deliverable presented case studies of the EuroSea work across various levels of the science-policy interface and provided a new outlook on how to further develop a science-policy interface for ocean observing and forecasting. In November 2022, WP8 organised the third and final EuroSea Anniversary Webinar[101] (see also under task Legacy below). Several Directorates General of the European Commission attended, and DG MARE presented progress on the Ocean Observations initiative. In May 2023, WP8 secured the EuroSea participation at a workshop at the European Maritime Day (EMD). The Workshop was co-organised by EuroGOOS and EOOS, Ifremer, EuroFleets+, Esprix de Velox, Euro-Argo ERIC, and EMODnet, with support from several other initiatives. It promoted the importance of coordination and sustainability in Europe's ocean observations. EuroSea delivered its integrated vision on the marine knowledge value chain, from observations to services and innovations. In addition, EuroSea and some developed products and services were presented at a dedicated project stand. In September 2023, WP8 supported policy engagement at the EuroSea Symposium hosted by IOC-UNESCO in Paris, through inputs to the EuroSea Declaration[102] and outreach. In October 2023, EuroSea supported the session on "Ensuring Ocean knowledge in the Age of the Digital Ocean" during the EurOCEAN ocean science-policy conference in Vigo, Spain. EuroSea materials and messages were promoted on stage by Inga Lips (WP1, EuroGOOS) and Pierre Bahurel (Mercator Ocean International) while the WP8 co-leaders attended the event to discuss the project work and legacy with policymakers and academic stakeholders.

Academia engagement continued through WP8 outreach to EuroSea partners (emails to partners about important initiatives and dissemination through the website and X/Twitter). Many EuroSea partners who are active on X/Twitter engage with the EuroSea account. The EuroSea exhibition was presented to a scientific and non-scientific audience at the institute-internal GEOMAR Science Day to internally communicate the progress of EuroSea and also receive feedback on the EuroSea exhibition. Furthermore, WP8 supported the advertisement for the "Ocean Best Practices Workshop VI – A virtual Global Meeting"[103] and together with WP1 colleagues contributed a workshop on "Ocean Best Practices & Ocean Policies"[104], the results of which were taken up in D8.3 Lessons Learned on Science-Policy Interface. In December 2022, the EuroSea itinerant exhibition was presented at the international marine science communication conference CommOCEAN 2022 in Sète, France. This allowed promoting EuroSea not only towards the scientific audiences and communicators attending the event, but also towards the students of several universities located in Sète, who attended CommOCEAN. This is also where the idea was born to support the Ocean Observers Initiative[99], which was presented there by Euro-Argo ERIC and WMO/OceanOPS, who are also EuroSea partners. In the following months, together with both partners, the WP8 team and the EuroSea project coordination, it was decided that part of the GEOMAR funds available in WP8 for engagement and dissemination should be invested in supporting the platform, which focuses on the production of educational materials for the field of ocean observation. Among other things, this money was used to pay a scientific editor who prepared educational material for specific target groups under the supervision of Euro-Argo ERIC and WMO/OceanOPS. EuroSea is thus investing in the present and future education of the next generation.

At the May 2022 annual meeting in Cadiz, WP8 organised a series of activities to engage the next generation of stakeholders. Students from the European inter-university alliance SEA-EU[92] were invited to attend the EuroSea meeting, present and discuss their posters, and co-chair/report on various workshops. A special

[101] https://www.youtube.com/watch?v=QKOJnGRjzy4&t=248s
[102] https://eurosea.eu/new/eurosea-declaration-for-ocean-observing-and-forecasting/
[103] https://www.oceanbestpractices.org/community-engagement/workshops/ocean-practices-obps-workshop-vi/
[104] https://eurosea.eu/download/ocean-best-practices-and-science-policy-interface-obps-iv/

focus on students and Early Career Ocean Professionals (ECOPs) was also given at the International Conference for Young Marine researchers (ICYMARE) which took place in Bremerhaven, Germany in September 2022. To raise further awareness for ocean observing and forecasting but also to listen to the needs, questions and concerns of the next generation of stakeholders, the young fresh minds of tomorrow, EuroSea WP8 decided to collaborate with AtlantECO[105] and WASCAL[106] to reach a bigger audience: The project coordinator as well as one of the young WP8 team members were invited to contribute to the AtlantECO Podcast series[107] on the topics "If you like your weather forecast, thank an oceanographer!"[108] and "Understanding the importance of the ocean, taking responsibility and making the next generation heard"[109]. In March 2023, a research cruise of the WASCAL Floating University was joint by one of the WP8 members to, on one hand-side, teach about the ocean observing value chain and EuroSea as part of an on-board science communication workshop jointly organised with the Christian-Albrecht University Kiel and to, on the other hand-side, really engage with young researchers and teachers on this adventurous trip. In addition, one of the team members took, with the EuroSea hat on, advantage of an individual invitation to a roundtable discussion on "Foreseeing Europe - Fresh Visions for the Future"[110] with school classes at the Futurium in Berlin to highlight the importance of sustainable ocean observations and forecasting for our present and future.

Industry engagement was conducted through the WP8 support towards the EuroSea demonstrators (WPs 5, 6, 7). WP8 supported the review of the demonstrator videos and promoted the activities via the website and Twitter/X. General industry engagement support was also conducted in WP8 task 8.3 (Exploitation) mentioned below.

Public engagement was conducted twofold during the 2022 European Researcher's Night: In Mallorca, Spain, WP8 partner SOCIB promoted the importance of ocean observing, monitoring and forecasting showcasing the EuroSea exhibition in Spanish and Catalan to make it especially attractive to the local audience; at the same time the GEOMAR team presented the EuroSea exhibition in English in Kiel, Germany.

In June 2023, WP8 promoted the project at the Oceans 2023 Conference in Limerick and at the ASLO Aquatic Sciences Meeting 2023 in Mallorca, Spain. In October 2023, WP8 secured the EuroSea participation at the 10th EuroGOOS International Conference, titled "European Operational Oceanography for the Ocean we want - addressing the UN Ocean Decade Challenges". The event took place in Galway, Ireland, on 3-5 October, and was an endorsed UN Ocean Decade activity. The EuroSea coordinator presented a future look on the development of ocean observing services in the plenary session titled "The Future of Operational Oceanography". Furthermore, WP8 supported outreach activities for the "Ocean Practices: OBPS Workshop VII"[111] held 9-20 October 2023.

[105] https://www.atlanteco.eu/
[106] https://wascal.org/
[107] https://shows.acast.com/atlanteco-podcast
[108] https://shows.acast.com/atlanteco-podcast/episodes/episode23
[109] https://shows.acast.com/atlanteco-podcast/episodes/episode26
[110] https://futurium.de/de/veranstaltung/foreseeing-europe-fresh-visions-for-the-future/foreseeing-europe-fresh-visions-for-the-future
[111] https://www.oceanbestpractices.org/community-engagement/workshops/ocean-practices-obps-workshop-vii-09-13-oct-2023-online/

WP8 also continued to support the EuroSea demonstrator work packages in their industry engagement activities by outreach - in addition to work conducted in task 8.3 Exploitation (see below).

General public engagement was conducted at several events around Europe: The EuroSea exhibition was showcased at the 25th Galway Science & Technology Festival in November 2022 (held in Galway, Ireland and organised by WP8 partner MI), at the 10th 'Science for all' fair in May 2023 (held in Mallorca, Spain and organised by WP8 partner SOCIB), at the Ocean Race Grand Finale in June 2023 in Genoa, Italy (organised by EuroSea partner ETT, and moderated by WP8 leader EuroGOOS), and at the EuroSea high-level Symposium on Ocean Observing and Forecasting in Paris, France. In early June 2023, the project and ocean observing networks were also presented as part of some GEOMAR outreach activities at the Ocean Race Fly-By and Meereschutztag in Kiel, Germany at a dedicated pavilion which was shared with the FerryBox developer SubCTech[112] and the Malizia Racing team[113].

In July 2023, WP8 released D8.5 "Lessons learned from EuroSea public participation activities". The report analysed the EuroSea exhibition as a case study of public engagement activity, assessing the impact of the exhibition through a survey and providing valuable information on participants' satisfaction and preferences. This information will contribute to the improvement of future public engagement activities by better understanding the needs and interests of the public regarding ocean observing and forecasting.

The public engagement will continue beyond the EuroSea lifetime through displaying the EuroSea exhibition(s): While the English version of the exhibition was donated to the Galway Aquarium in Ireland where it will become part of their main exhibition space, the Spanish and Catalan version of the exhibition will remain with EuroSea partner SOCIB at Mallorca, who plans to display them in the public space of a new building which is planned to be put in operation in 2024.

Task 8.2: Dissemination

Task leader: SOCIB, RBINS, Partners: EuroGOOS, GEOMAR

The activities in this task and in the Engagement task naturally intertwine seamlessly. They are closely aligned with each other. Although the management and implementation of the individual activities were carried out by different partners depending on responsibilities and expertise, there was always very close communication and coordination within WP8. The implementing partners were thus always involved in both tasks. While the progress report of the engagement task has already dealt with individual activities and the corresponding target groups, the following section focuses on what materials were produced and what tools were used to enable successful engagement.

To raise awareness and dissemination of the EuroSea project to the wider public, the EuroSea exhibition[93] (MS20) has been set up. It has been submitted as milestone MS20 on 29 July 2022. Aimed at the general public, the EuroSea itinerant exhibition is composed of 12 printed panels showcasing texts, illustrations, audiovisuals and a photobooth (Figure 15) to present how EuroSea improves and integrates the European ocean observing and forecasting system and delivers information and solutions to support decision-making in the areas of climate, ocean health and maritime activities. The lead beneficiary SOCIB produced a second identical exhibition in Spanish and Catalan alongside the English version to make the exhibition more attractive to a wider audience in Spain. In the first months after its launch, the exhibition has been displayed

[112] https://subctech.com/
[113] https://www.team-malizia.com/

at 4 events targeted towards a diverse audience, including multidisciplinary scientific attendees and the general public.

Figure 11. The EuroSea exhibition photo booth at the EuroSea Symposium 2023

Regarding the EuroSea communication channels managed by WP8, the EuroSea website[96] continued to represent a key instrument in the EuroSea dissemination activities. A total of 31 news articles have been published on the EuroSea website between May 2022 and October 2023. Another communication instrument is the EuroSea X (Twitter) account[94]. With a total of 96 tweets, the account has reached 1.620 followers. The EuroSea YouTube channel[95] published 8 new videos, representing 849 new visualizations and 13 new subscribers, in this reporting period. These included demonstrator videos about the developed OSPAC tool (WP5) and the Observational and Warning System (WP6), a report video about the engagement with the WASCAL Floating University, but also the recording of the 3rd Anniversary Webinar in November 2022 and the recordings of the 4 different sessions of the EuroSea Symposium conducted in September 2023.

The usage of the EuroSea X (Twitter) account has been significantly intensified during this reporting period: All items published on the EuroSea website as well as the all new YouTube videos were always accompanied by at least one tweet. The tool was also used to announce and retweet dissemination activities of the EuroSea partners related to their EuroSea activities. The EuroSea Symposium on Ocean Observing and Forecasting which took place at the UNESCO headquarters in September 2023 was supported by a campaign before and after the event.

Two public newsletters were issued during the previous reporting period (in October 2021 and April 2022). However, WP8 observed that the subscription and open rates for these newsletters were relatively low. As a result, the decision was made to not continue the production of the EuroSea newsletters. Instead, it was decided to focus on strengthening other public communication channels, such as EuroSea Twitter and YouTube, and to also engage more actively with related initiatives via their successful newsletters, notably EuroGOOS, European Marine Board, POGO, and GOOS, e.g. the EuroSea high-level Symposium on Ocean Observing and Forecasting in September 2023 was advertised through all these newsletters.

In addition to the communication and dissemination materials developed solely for EuroSea, teaching materials have now been developed, refined and partly re-illustrated by supporting the Ocean Observers Initiative[99], which do not directly disseminate the project but rather contribute to the larger understanding of ocean observations. Materials such as videos, instructions for group activities and experiments, quizzes, documentations, and games serve as an important tool to bring the topic to especially younger generations in an entertaining, interactive and often playful way. The materials are freely available on the website. The initiators (Euro-Argo ERIC and OceanOPS/WMO) will continue this initiative after EuroSea. In addition to the materials available on the website, the production of a comic book is planned. The creation of the illustrations (Figure 16) for this book were also supported by EuroSea.

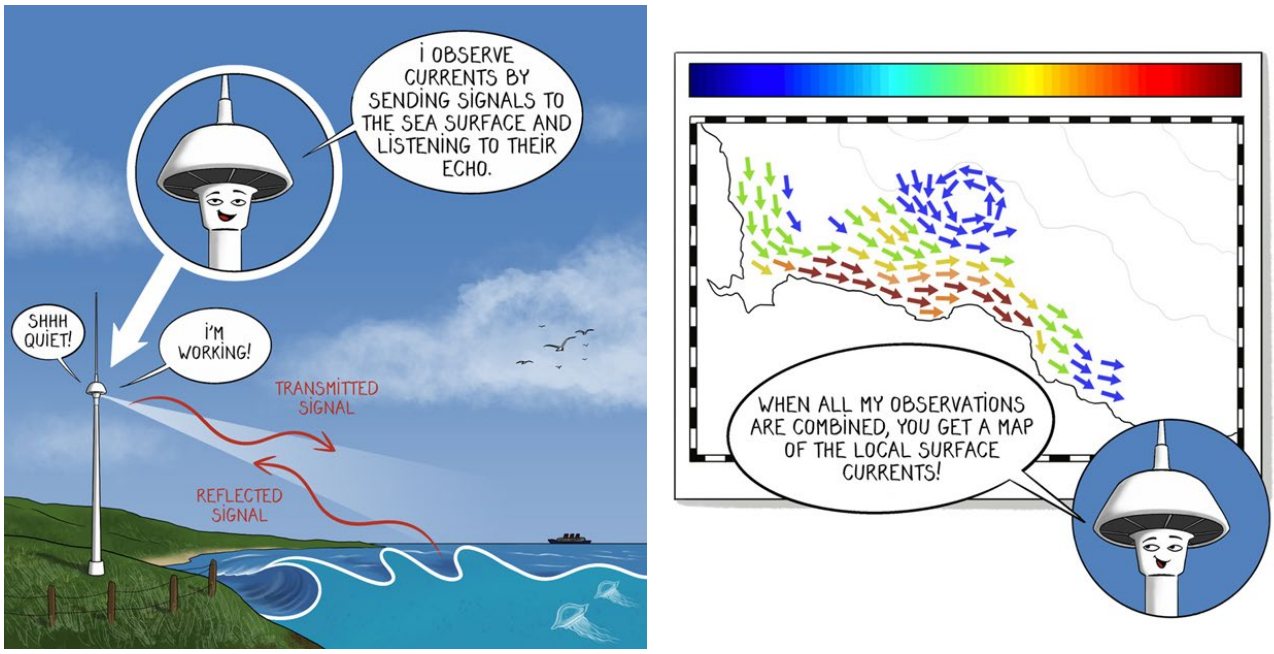

Figure 12. Comic illustration of a High-frequency radar developed by the Ocean Observers initiative

In order to engage with students of different academic backgrounds and show them the diversity of career opportunities in ocean observing and forecasting, 9 different career profiles[114] (Figure 17) were created based on actual CVs and individual interviews with EuroSea colleagues. These profiles were used as a basis for career workshops with students at the ICYMARE conference and after the research cruise in the

114 https://eurosea.eu/download/eurosea-job-profiles-brochure-2022/?wpdmdl=5178&refresh=6536abdfd3b7c1698081759

framework of WASCAL. The information and experiences shared here have created very positive feedback and high interest.

Figure 13. EuroSea career profiles

In addition to the digital dissemination activities, the WP8 team and the project coordination also increasingly sought and used personal exchange during this period: i.e. The project was presented by the project leader at the following events, among others: The open informal consultative process by UNCLOS at the UN headquarters in New York in June 2022, The Ocean Conference in Lisbon in June 2022, Malizia Ocean Festival in Hamburg in September 2022, EU-Canada Ocean Partnership in Brussels in October 2022, GCOS Science Conference in Darmstadt in October 2022, GEO Week in Accra in November 2022, UNFCCC COP27 in Sharm el Sheik in November 2022, G7 FSOI in Berlin in November 2022, EuroGEO meeting in Athens in December 2022, European Maritime Day in Brest in May 2023, The Ocean Summit in Aarhus in June 2023, Digital Ocean Forum in Brussels in June 2023, WCRP/GCOS climate cycle workshop in Paris in June 2023, IOC Assembly in Paris in June 2023, EuroSea final conference and side-meetings in Paris in September 2023, Sustainable Blue Economy Partnership meeting in Brussels in September 2023, EuroGOOS conference in Galway in October 2023, WCRP Open Science Conference in Kigali in October 2023.

To raise awareness and dissemination of the EuroSea project to the wider public, the EuroSea exhibition has been displayed at 6 events targeted towards a diverse audience, including multidisciplinary scientific attendees, policy stakeholders and the general public. In addition to the exhibition itself, EuroSea flyers were created based on the design and content of the exhibition. The flyers were created in English, Italian and German and were distributed at various events.

In order to strengthen the visibility of the products developed in the demonstrator WPs at in-person events, a roll-up was designed for each of the 4 defined key exploitable results (KERs; Figure 18). These were displayed for the first time at the Symposium and are also available on the EuroSea website[115]. The aim is for the partners to continue using them at future in-person events to present the products developed in EuroSea to interested stakeholders, even after the project is finished.

Figure 14. Developed rollups for EuroSea key exploitable results (KERs)

Beyond the WP8-initiated activities mentioned here, many individual activities were also carried out by individuals, task teams and work packages. A list of many of those activities can be found in section 3 Dissemination. These were supported by WP8 in the best possible way by sharing the information via the EuroSea communication channels and by forwarding to other initiatives' communication teams to be included in their newsletters.

[115] https://eurosea.eu/outputs-reports/

Task 8.3: Exploitation

Task leader: MI, Partners: ISPRA, SciencEthics

WP8 coordinated the activity of the EuroSea Innovation and Stakeholder Committee (ISC). The committee met a number of times, including one in-person meeting during the EuroSea General Assembly in Cadiz on 12 May 2022. The ISC provided constructive feedback on the EuroSea exploitation activities and the level of innovation in the project at the EuroSea General Assembly on 13 May 2022.

The WP5, WP6 and WP8 partners attended the Sustainable Ocean Summit 2022 in Barcelona from 17-18 October 2022. WP5 partners presented on the OSPAC software and received some useful questions and feedback on the use of the OSPAC software. The Sustainable Ocean Summit was organised by the World Ocean Council (WOC) and the OSPAC presentation was enabled through the EuroSea connection with Innovation and Stakeholder Committee member Christine Valentin, who worked for the WOC at the time. WP5, WP6 and WP8 partners also attended the Global Blue Finance Summit (BlueFIN 22) in Barcelona on 19 September 2022. This event provided information on funding and investment opportunities for further development of the EuroSea KERs.

Deliverable 8.6 on the economic impact of ocean observations was submitted in October 2022. This study assessed the economic value of ocean observations in qualitative terms. The report focused on the main EuroSea demonstration products and services with potential for commercialisation that were identified in the Exploitation Strategy.

The EuroSea Business Plan (D8.8) was submitted in June 2023. The deliverable consisted of detailed business plans for the four KERs with the most potential for commercialisation that were identified in the EuroSea Exploitation Strategy (D8.4) and were previously published on the Innovation Radar platform: Oceanographic Services for Ports And Cities (OSPAC software) – real time alert to provide forecast of sea conditions (WP5); Solution for marine sensors to measure and forecast oxygen, heat and pH related Extreme Marine Events on-site for aquaculture (WP6); Low maintenance tide gauges (WP5); and Prototype sea level planning and scenario visualisation tool (WP5). D8.8 built on the work done in the EuroSea Exploitation Strategy and includes additional information for each KER on the Technology Readiness Level (TRL), Commercial Readiness Level (CRL), Market Analysis, Business Model Canvas, Competitor Analysis, Investment Sources and an Intellectual Property (IP) plan for the management of IP Rights (IPR).

EuroSea partners availed of external expertise provided through the EU funded Horizon Results Booster (HRB) services in relation to project business plan development. The aim of this service was to assist beneficiaries to bring their results closer to the market by developing an effective business plan. The HRB experts were LC Innoconsult International, and they recommended to focus on four EuroSea KERs for detailed analysis in the EuroSea business plan deliverable. Meetings were held in January and February 2023 to progress the business plans.

In addition, and to aid the delivery of the business plan, EuroSea members from the Marine Institute attended a training course on exploitation planning and the process of commercialising project results, customer validation and business model selection in February 2023. Periodic expert advice on the business development plans including IPR, organised by WP8, was provided to EuroSea partners by Sapien Innovation Limited and this also fed into D8.8. Generally, WP8 worked closely with the WP6 partners to develop the Business plan for EuroSea demonstrators which also fed into the WP6 “Sustainability and Business Plan” (D6.5).

Task 8.4: Sustaining legacy

Task leader: SciencEthics to EuroGOOS, Partners: ISPRA, SOCIB, RBINS, MI, EuroGOOS, GEOMAR

During the main time of the project the legacy task was implemented through two major activities: 1) The impact monitoring protocol, tracking and reporting (partners' reports, impact workshops at annual meetings, follow-up and meetings with WP and task leaders, etc), and 2) EuroSea Anniversary webinars discussing the EuroSea progress towards sustained legacy with stakeholders. In the reporting period, WP8 held an in-person impact workshop during the 3rd Annual Meeting in Cadiz. The workshop involved members of the consortium and steering committee, as well as of the Advisory and the Innovation and Stakeholder Boards. It provided inputs for D8.3 Lessons Learned on Science-Policy Interface and the impact pages on the EuroSea website.

Furthermore, deliverable D8.9 provides recommendations to increase common responsibility towards the ocean and support its sustainability. This report summarizes how the six articulations of the responsible research and innovation (RRI) approach were applied in the EuroSea project. In addition, it offers recommendations to boost the societal benefits provided by inclusivity, equality, ethics, transparency and collaborative co-design and co-creation in the research and innovation process applied to ocean observing.

In November 2022, the third and last EuroSea Anniversary Webinar took place to discuss progress towards legacy with policy and academic stakeholders. The webinar was well attended and included updates from the European Commission on the preparation of the Ocean Observations initiative. In September 2023, after 3.5 years of work - the results of the impact monitoring, tracking, and reporting were delivered on the EuroSea website. The impact pages[116] were very well received and promoted during the EuroSea final annual meeting and high-level Symposium in September 2023, hosted by UNESCO in Paris. Furthermore, a comprehensive impact registry was created by WP8 including nearly 100 EuroSea impacts. A summary impact report was delivered in October 2023 for the European Commission and partners. The EuroSea impact tracking and reporting represented the first known such attempt in a European ocean observing project. The EuroSea Legacy Report (D8.12, to be submitted in November 2023) will build on this process to deliver a concise brochure promoting the key impacts and messages of EuroSea as an integrated project comprising all elements of the marine knowledge value chain.

Cooperation and interaction with other EuroSea WPs

The WP8 is intrinsically based on cooperation with all consortium partners. Interactions are often fast and efficient thanks to the personal knowledge of each other in the consortium, despite it being a very big partnership. Therefore, it was decided to not list the interactions here, since they are not all monitored and sometimes happen quickly and informally.

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
AtlantECO	• Contribution to podcast series on “Stories of the Atlantic Ocean through human adventures and scientific advances”
WASCAL	• Science communication workshop and workshop on career opportunities in ocean observing and forecasting
Ocean Race	• EuroSea Day in Genoa, Italy - side event at the Grand Final of the Ocean Race

[116] https://eurosea.eu/impacts/

SubCTech, Malizia, GreenBoat	• Joint pavilion at the Ocean Race Fly-By and Tag der Meeresschutzstadt in Kiel, Germany
SEA-EU	• Invitation of 11 SEA-EU students to EuroSea Annual Meeting in Cadiz, Spain
EuroGOOS, GOOS, EMB, POGO	• Dissemination activities via their newsletters

Achieved main results

Deliverables		
D8.3	Lessons learnt on science-policy interfaces	✓
D8.5	Lessons learnt from the EuroSea public engagement activities	✓
D8.6	Report on economic value of ocean observations	✓
D8.7	Lessons learnt on public-private interfaces	✓
D8.8	Business plan for EuroSea demonstrators	✓
D8.9	EuroSea recommendations on RRI in OO	✓
D8.10	EuroSea Guide on communication and dissemination activities for enhanced visibility of innovation in ocean observing and forecasting for a sustainable ocean	✓
Milestones		
MS20	Itinerant exhibition	✓
MS31	Training webinars	✓
Others (optional)		
	Dedicated EuroSea impact section on project website	✓

WP9 - Project Coordination, Management and strategic ocean observing alliance

Lead: GEOMAR

Objectives
• Provide top level management of the project to ensure aims of the project are efficiently and effectively met, on time and with the resources budgeted and that knowledge and innovation are properly managed
• Provide effective reporting and communication within the project, between partners and stakeholders and between the consortium and the EC
• Provide support for and activities aimed at project internal integration
• Provide connections and interfaces with other projects funded under this topic

Summary of progress towards WP objectives

The project coordination unit (PCU) carried on with the general tasks of coordinating this large project. Weekly meetings between the project manager and coordinator and monthly meetings with the EuroSea Steering Committee (SC) were held.

Early in this reporting period a major effort was in organizing and conducting the 3rd EuroSea annual meeting in Cadiz, Spain, which turned to be out a positive push for the project. In addition to the continuous effort to coordinate the project and interact with the many partners of the consortium, WP9 was also responsible for organizing the 4th, and last, project meeting and assembly. This was held in Paris, at the HQ of UNESCO, and included one day with invited (high-level / important) guest that gave their input to various aspects of ocean observing and forecasting. This event turned into a kind-of "grand finale" of the action (although not the end of the action), and EuroSea was recognized by our invited guests as having played a very important role in Europe (and globally) for the ocean observing and forecasting system.

The WP9 team coordinated and led initiatives to continue the activities of EuroSea in new format and projects. This was partly successful with several partners engaged in new EU-funded projects with relation to the objectives of EuroSea. Several partners of EuroSea, including the WP9 team, has engaged with the sustainable blue economy partnership to find new ways to work together towards delivery of ocean information and forecasts that is beneficial, if not necessary, for the blue economy. These discussions are still active at the time of writing.

The WP9 team reads, comments on, and provides feedback on all deliverables and milestones produced by the consortium. Obviously, the WP9 team submits those to the portal, and has good and regular contacts with the project and policy officers of the action.

Detailed progress per task (or subtasks)

Task 9.1: Project coordination and management

Task leader: GEOMAR

The project coordination continued to provide administrative, coordinating and advisory support to all project partners. In May 2022, the consortium met for its 3rd General Assembly and Annual Meeting in Cadiz, Spain. This in-person meeting was co-organised with partner CSIC and hosted by the University of Cadiz. A

high number of participants, with representatives from most partners and from almost all task teams, led to a very good meeting, which definitely resulted in a new WE-feeling and an important positive push for the project. Some members of both advisory boards (Innovation and Stakeholder Committee - ISC & International Scientific and Technical Advisory Board - ISTAB) also attended this meeting, which was not only used for hybrid board meetings but also for personal feedback rounds with the PCU. Both boards presented their feedback directly to the consortium during the General Assembly.

Even during this reporting period, the PCU was still confronted with partly unexpected consequences and after-effects of the pandemic. One drastic effect was certainly that the project partners OceanNext and SciencEthics were forced to leave the project consortium in June 2022 due to the impact of Covid on their companies.

The Steering Committee, consisting of all WP leaders and co-leaders, continued to meet online once per months. Chaired by the project coordinator, it substantially supported the established communications and collaborations among the WPs and with the PCU. After sending them out monthly in the first half of the project, only a few more internal newsletters were sent to the consortium and the advisory boards during this period. This activity was discontinued in August 2022 due to insufficient time capacities. Only recently was the coordination informed that the boards in particular would have liked these newsletters to continue in order to be regularly informed about the progress of the project.

The PCU continued to review all documents (deliverable and milestone reports) not only in terms of form but also in terms of content and provided appropriate feedback to the authors. Although this led to time bottlenecks, especially in October 2022 (end of the official interim reporting period with almost 20 documents to be submitted), which sometimes resulted in late submission, this approach paid off overall, as it substantially strengthened internal communication between the PCU and the task teams.

General structures for fast communication and exchange with the consortium were maintained and regularly updated (mailing lists, cloud, reminders, calendar) as in the previous reporting periods.

The good communication with the responsible project and policy officers at the European Commission was continued. Three amendments of the EuroSea Grant Agreement were successfully implemented.

The project coordinator represented the project at various events, shared achievements and results, and promoted the general interests of the EuroSea consortium. In October 2022 the PCU organised a small policy feedback meeting with representatives of different EC Directorate Generals in order to inform them about the EuroSea progress and receive feedback and strategic advice for the project.

In November 2022, the PCU was instrumental in organising the 3rd EuroSea Anniversary Webinar, which again had audiences and speakers from politics, industry and academia. In December 2022, the 2nd Periodic Report covering project months 19-36 was submitted to the European Commission. The related review meeting took place as in-person meeting in Brussels in February 2023. Although the overall evaluation of the project by the external reviewers was positive, the consortium received constructive feedback on many of the deliverables submitted during that period as well as on the activities conducted in the demonstrator WPs. Many of the recommendations were considered to improve the documents and activities.

In January the PCU started together with the GOOS team of partner IOC-UNESCO the planning of the EuroSea final General Assembly (GA, day 1 and 2) as well as the planned high-level Symposium on Ocean Observing and Forecasting (day 3) which should take place at the UNESCO headquarters in Paris from 19-21 September

2023. In April 2023, a supporting task team with members of some of the WPs was built in order to support the conceptual planning of the GA and the Symposium. The task team met once every two weeks and was decisively involved in the success of the events. While the final project meeting on day 1 with reports from all work packages and presentations on different topics reviewed the last months of the project, day 2 was dedicated to 'EuroSea Legacy': In a one-day workshop, different EuroSea teams shared their experiences and results from the close cooperation with the different stakeholders within their work packages with the GOOS co-design teams. Alternating between presentation and lively discussion, the main focus was on dialogue and exchange between the participants and the audience. The EuroSea experiences and lessons-learned will be incorporated into future GOOS co-design activities. Although the number of project-internal participants was significantly lower than the year before in Cadiz and only about half of the EuroSea partners were represented at the GA, the results presented, the discussions held and also the personal conversations ensured a worthy and successful final project meeting.

On the final day, day 3, the high-level Symposium on Ocean Observing and Forecasting brought together policy, science, and industry stakeholders to discuss and formulate strategies on sustainable ocean observing and forecasting. With representatives from the European Commission, IOC/UNESCO and many leading marine research institutions among experts from various industry fields and with over 160 registrations the event was a standing testament to Europe's strong commitment to strengthening the ocean observing and forecasting infrastructures, governance, and dialogue with the users of marine space and resources. Thus, this event set an important signal for the ocean observing and forecasting community and was a worthy conclusion for the EuroSea project. A recording of the event can be viewed via the EuroSea website[117] or the EuroSea Youtube channel[118].

Task 9.2: Interfaces to other projects under this topic

Task leader: GEOMAR, Partners: HCMR, IFREMER

The project manager participated in the monthly All-Atlantic project manager meeting organized by the AANChOR project to share experiences, exchange about the project progresses and inform each other about planned outreach activities and events.

However, although there are certainly overlaps in the objectives of many of the project, the EuroSea PCU found it very difficult to initiate any substantial collaboration. We attribute this in part to the fact that strategic and coordinated collaboration, given the size of the project consortia and the current circumstances, involves a considerable coordinative effort that the projects cannot cover with the given capacities. However, this issue was identified by the group of project managers and it is currently discussed to combine the experiences with a list of possible solution in a joint document addressed to the European Commission.

Nevertheless, there is an ongoing exchange with coordinators, managers, communicators, scientists and other partners from projects in the wider field of ocean observing and forecasting, even if this exchange often takes place sporadically at jointly attended events and discussion groups. There is an ongoing sporadic closer

[117] https://eurosea.eu/new/eurosea-symposium-highlights-the-urgency-of-integrated-ocean-observing-and-forecasting/

[118] https://www.youtube.com/watch?v=Q2wE-Byd41g&list=PLQbvHHhGCSJJ4vPMKAhPPynCkbEVO-Fdu

exchange with the Blue-Cloud project, as the EuroSea project coordinator is a member of the Blue-Cloud External Stakeholder & Expert Board.

Based on the work accomplished in EuroSea and conversations and discussions with the ocean observing and forecasting community within and outside EuroSea, the project coordinator summarized some of the main take home messages from EuroSea on the technical innovation and data management needs for the European Ocean Observing and Forecasting System in deliverable D9.3 which was submitted in September 2023. There he shares a personal view forward on what the community still has to accomplish using the prism of the ocean observing value chain. He articulates needs in the areas of governance and coordination, design, network integration and, finally, data integration, assimilation and forecasting. The content of D9.3 and D1.8 (Final Report of EOOS Implementation Plan) are meant to be merged and published as an article in the remaining time of the project.

Cooperation and interaction with other EuroSea WPs

Co-operator	WP activities
All WPs	• Day to day communication • Organization of monthly SC meetings • Maintenance of project mailing lists and project cloud space

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
EMODnet, Blue-Cloud	• Organisation of joint workshop about "Ocean observations, marine data and services for the European Green Deal" at European Maritime Day 2022
All-Atlantic projects	• Monthly attendance of joint project manager meeting to exchange about the ongoing projects, events and outreach activities

Achieved main results

Deliverables		
D9.3	Ocean Observing Needs	✓
D9.4	Action Progress Report #3	✓

WP10 – Ethics Requirements

Lead: GEOMAR

Objectives
• Ensure compliance with the 'ethics requirements' set out in this work package

Summary of progress towards WP objectives

No new activities were carried out under this work package during the reporting period.

3. Dissemination

The lists below may only be a part of the activities carried out and do not claim to be exhaustive.

Scientific publications

- Mignot A, Claustre H, Cossarini G, D'Ortenzio F, Gutknecht E, Lamouroux J, Lazzari P, Perruche C, Salon S, Sauzède R, Taillandier V. Using machine learning and Biogeochemical-Argo (BGC-Argo) floats to assess biogeochemical models and optimize observing system design. Biogeosciences. 2023 Apr 12;20(7):1405-22.…
- Gasparin F, Lellouche JM, Cravatte SE, Ruggiero G, Rohith B, Le Traon PY, Rémy E. On the control of spatial and temporal oceanic scales by existing and future observing systems: An observing system simulation experiment approach. Frontiers in Marine Science. 2023 Jan 31;10:1021650.…
- Barceló-Llull B, Pascual A. Recommendations for the design of in situ sampling strategies to reconstruct fine-scale ocean currents in the context of SWOT satellite mission. Frontiers in Marine Science. 2023 Apr 11;10:1082978.
- Bàrbara Barceló-Llull, Ananda Pascual, Aurélie Albert, Jaime Hernández-Lasheras, Stephanie Leroux, & Baptiste Mourre. (2022). Dataset generated to evaluate in situ sampling strategies to reconstruct fine-scale ocean currents in the context of SWOT satellite mission (H2020 EuroSea project) (V1.0) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.6798018
- Bàrbara Barceló-Llull. (2023). Codes generated to evaluate in situ sampling strategies to reconstruct fine-scale ocean currents in the context of SWOT satellite mission (H2020 EuroSea project) (v1.0.0). Zenodo. https://doi.org/10.5281/zenodo.7543697
- Dayan et al., 2022: Diversity of marine heatwave trends across the Mediterranean Sea over the last decades. In: Copernicus Ocean State Report, issue 6, Journal of Operational Oceanography, 15:sup1, 1-220, doi: https://doi.org/0.1080/1755876X.2022.2095169.
- Dayan, H., R. McAdam, M. Juza, S. Masina and S. Speich, 2023: Marine heat waves in the Mediterranean Sea: an assessment from the surface to the subsurface to meet national needs. Frontiers in Marine Science. Front. Mar. Sci. 10:1045138. https://doi.org/10.3389/fmars.2023.1045138.

Presentations

- Lips, U., Stakeholder engagement, Presentation of the updated EuroSea Task 6.3 indicators, discussion of their suitability for HELCOM assessments indicators, discussion of their suitability for HELCOM assessments, 12/05/2022-13/05/2022, HELCOM IC State & Conservation 1-2022, https://portal.helcom.fi/meetings/IC%20STATE%20-%20CONSERVATION%201-2022-1033/MeetingDocuments/Memo%20of%20IC%20STATE%20and%20CONSERVATION%201-2022.pdf
- Samlas, O. et al, EGU 2022 (OS4.8), oral presentation, 23/05/2022-27/05/2022, https://www.egu22.eu/, "Presentation ""Potential of CMEMS products for assessing eutrophication status and natural variability in the north-eastern Baltic Sea."""
- Asselot, R., EGU2022, oral presentation, 23/05/2022-27/05/2022
- Barceló-Llull, B. et al., Optimizing multi-platform sampling strategies to anticipate SWOT validation, poster, 23/05/2022, ESA Living Planet Symposium 2022, Bonn, Germany

- Juza, M., Sub-regional marine heat waves in the Mediterranean Sea, oral presentation, 26/05/2022-26/05/2022, EGU 2022 (OS2.4)
- García León, M., OSPAC (Operational Services for Ports and Cities), Product demonstration, 01/06/2022, Dissemination on the results through social media and the web
- Liste Munoz, M., High-Resolution Forecasting for Harbour-Beach Interactions. A Mediterranean Application. oral presentation, 26/05/2022, EGU General Assembly, https://www.egu.eu/
- Tanhua, T. The open informal consultative process by UNCLOS, UN HQ, New York, presentation and discussion, 04/06/2022-10/06/2022
- Carlos Barrera, Encuentro del Atlantico La Palma 2022, oral presentation, 24/06/2022, https://encuentrodelatlantico.com/
- Tanhua, T., The Ocean Conference, presentation & panel discussions, 27/06/2022-01/07/2022, Lisbon
- Wilmer-Becker, K., EuroSea/OceanPredict workshop 1, oral presentation, hosting and supporting panel discussion, 29/06/2022-01/07/2022, https://oceanpredict.org/archived-events/eurosea-oceanpredict-workshop-june-2022/#section-home
- Barceló-Llull, B. & Pascual, A. (2022), Evaluating in situ sampling strategies for SWOT satellite validation, oral presentation, 29/06/2022, EuroSea/OceanPredict workshop, Exeter, UK (hybrid), Evaluating in situ sampling strategies for SWOT satellite validation.
- Cusack, C., EuroSea/OceanPredict Workshop on Ocean Prediction and Observing System Design for the UN Ocean Decade, oral presentation / Session Chairs, 29/06/2022-01/07/2022
- Reyes, E., EuroSea/OceanPredict workshop, oral presentation. https://oceanpredict.org/docs/Documents/Projects/EuroSea/WS1/Oral/Session3/3.5-EuroSea_OceanPredict_HFR_DA_EReyes_et_al_FV.pdf, 29/06/2022-01/07/2022, EuroSea/OceanPredict workshop, https://oceanpredict.org/news/2022/11/eurosea-oceanpredict-workshop-report-published
- Barrera, C., Semana de la Administracion Abierta, oral presentation (streaming), 30/06/2022, Streaming, https://www.plocan.eu/charla-semana-de-la-administracion-abierta/
- Juza, M., Sub-regional marine heat waves: lessons learnt and web application, oral presentation, 30/06/2022, OceanPredict-EuroSea meeting
- Barrera, C., Networking Fridays AIR Centre, virtual presentation, 01/07/2022, https://www.aircentre.org/netfridays/
- Révelard, A., Ocean Integration: how can we improve coordination between observing activities?, oral presentation, 01/07/2022, EuroSea/OceanPredict workshop session 4
- Barceló-Llull, B. & Pascual, A. (2022), Design of in situ sampling strategies to reconstruct fine-scale ocean currents in the context of SWOT satellite validation, oral presentation, 06/07/2022, EOF-ISMS, Las Palmas de Gran Canaria, Spain (hybrid)
- Barrera, C., International Symposium on Marine Sciences (ISMS) 2022, oral presentation, 06/07/2022-08/07/2022, https://isms-canarias.com/
- Barrera, C., Marine Robotics Summer School 2022, Virtual presentation, 15/07/2022, https://www.mitportugal.org/activity/2022-marine-robotics-summer-school/speakers
- Barceló-Llull, B., #VirtualPosterSession #FilaChange, How to design in situ sampling strategies to reconstruct fine-scale ocean currents in the context of #SWOT satellite validation? @bbarcelo_ocean and @anandapascual1 identified: Consolidated Results Incoming Opportunities

and Next Challenges, Virtual Poster Session on Twitter during the FilaChange Workshop, 26/08/2022, https://twitter.com/SWOT_AdAC/status/1563197631635292161

- Barceló-Llull, B. & Pascual, A., Invited speaker, oral presentation, 31/08/2022, FilaChange workshop, Paris, France, Finescale ocean currents in the Med Sea
- Barrera, C., IMO Seminar on Development of a Regulatory Framework for Maritime Autonomous Surface Ships (MASS), virtual presentation, 05/09/2022-06/09/2022, https://www.imo.org/en/OurWork/Safety/Pages/MASS.aspx
- ICES ANNUAL SCIENCE CONFERENCE 2022, oral presentations, 19/09/2022-22/09/2022, https://www.ices.dk/events/asc/ASC2022/Pages/default.aspx, WP6 participated in two sessions related to modelling and oceanography ICES Annual Science Conference 2022; Network Session: Advancing the pathways for oceanography to ecosystem science and advice [WP6 Diego Alveraz was an invited speaker and presented work related to T6.2] & Theme Session A: Oceanography and ecosystems in the North Atlantic: science and operational services [Diego Pereiro et al. gave a talk on EuroSea Tasks 6.1 & T 6.4]
- Lips, I., Towards European Ocean Observing System, oral presentation, 03/10/2022-04/10/2022, EU-Canada 1st Ocean Partnership Forum
- Novellino, A., Data harmonisation recommendations for ocean observation networks, oral presentation, 04/10/2022, IEEE - MetroSea 2022, https://www.metrosea.org/ms2022/conference-schedule
- Asselot, R., 7th Argo Science Workshop, oral presentation, 11/10/2022-13/10/2022
- Barrera, C., Jornadas MARCET-II, oral presentation, 18/10/2022, https://www.ulpgc.es/noticia/2022/10/14/primera-jornada-transferencia-conocimiento-del-proyecto-marcet-ii-canarias
- Révelard, A., Organizational best practices to foster cooperation across disciplines/ platforms/ networks, oral presentation and discussion session, 13/10/2022, Ocean Best Practices System workshop VI, https://docs.google.com/document/d/1Oh4wMcEtWkJyXe6Jn-4N6t9nL9AJjLYD_CjAiM4LcVs/edit
- García León, M., SMART Ocean-SMART Industries: Ocean and Climate Data Collection from Vessels, Platforms and Cables during the U.N. Decade of Ocean Science and Beyond, oral presentation (Keynote speaker), 17/10/2022-19/10/2022, Sustainable Ocean Summit 2022 and Global Blue Finance Summit – Barcelona, https://www.sustainableoceansummit.org/sos-program/
- Barrera, C., Jornadas Tecnica sobre Buques Autonomos - MITMA, oral presentation, 24/10/2022-25/10/2022, https://www.mitma.es/marina-mercante/i-jornada-tecnica-sobre-buques-autonomos
- Barrera, C., Glider School 2022, oral presentation, product demonstration, etc., 24/10/2022-28/10/2022, https://gliderschool.eu/
- Tanhua, T., GEO Week, Accra, presentation & discussion, 01/11/2022-04/11/2022
- Révelard, A., Ocean Integration: towards more integrated observations, oral presentation, 15/11/2022, General Assembly of ILICO, France's multi-agency infrastructure for coastal ocean observations
- Novellino, A., The role of data and data process for ocean and environment understanding and sustainable exploitation, oral presentation, 13/01/2023, Italian Day - The Ocean Race
- Novellino, A., The role of data and data process for ocean and environment understanding and sustainable exploitation, oral presentation, 24/02/2023, Italian Day - The Ocean Race - Cape Town

- Pereiro Rodriguez, D., GOE Seminar ICMAN-CSIC 23, oral presentation, 23/03/2023, GOE Seminar ICMAN-CSIC
- Strasser, F.-E., EuroSea collaboration with the WASCAL Floating University, pre-cruise workshops: focusing on the Ocean Observing Value Chain and storytelling techniques to in-depth training sessions aboard the vessel centered on science communication, 28/03/2023-11/04/2023, https://eurosea.eu/new/engaging-the-next-generation-of-ocean-professionals-eurosea-joining-the-wascal-floating-university-ii-on-the-rv-polarstern/, https://youtu.be/b68FS74vPfU?feature=shared
- Novellino, A., The role of data and data process for ocean and environment understanding and sustainable exploitation, oral presentation, 20/04/2023, Italian Day - The Ocean Race Village - Itajai Brasil
- Asselot, R., EGU2023, poster presentation, 24/04/2023-28/04/2023
- Pereiro Rodriguez, D., An Observational and Warning System for the Aquaculture Sector in European Waters, oral presentation, 23/04/2023-28/04/2023, EGU General Assembly 2023
- Revelard A., J. Tintoré et al., 2023: the needs for enhanced ocean integration for enhanced global ocean observing. GOOS steering com. Meeting, Halifax. 26/04/2023
- Revelard A., J Tintoré et al., 2023: ocean integration, challenges for ocean observing. National Academy of Sciences, Ocean Sciences Board. 18/05/2023
- Asselot, R., GMMC2023, poster presentation, 31/05/2023-02/06/2023, Scientific days LEFE/GMMC 2023
- Novellino, A., The role of data and data process for ocean and environment understanding and sustainable exploitation, oral presentation, 05/06/2023, Italian Day - The Ocean Race Village - Aarhus - Denmark
- Novellino, A., The role of data and data process for ocean and environment understanding and sustainable exploitation, oral presentation, 12/06/2023, Italian Day - The Ocean Race Village - The Hague, the Netherlands
- Wimart-Rousseau, C., Quality enhancement of tropical carbon fluxes, poster, 05/06/2023-16/06/2023, SOLAS Summer School 2023, https://www.solas-int.org/events/summer-school-22-23/in-person-summer-school-23.html
- Novellino, A., Towards a user-focused, interdisciplinary, and responsive European ocean observing and forecasting system – EuroSea, oral presentations, roundtable discussions, 28/06/2023, The Ocean Data Week - The Ocean Race - Grand Finale Genova
- Simpson, P., Co-Designing Ocean Forecasting: Working Together to Deliver as One, oral presentation, panel discussion, 27/09/2023-28/09/2023, https://www.mercator-ocean.eu/en/news/co-designing-ocean-forecasting-working-together-to-deliver-as-one/
- Bonnet Dunbar, M., Co-development of an Ocean Observatory with the Aquaculture Industry, oral presentation, 03/10/2023-05/10/2023, 10th EuroGOOS International Conference, Galway, https://marineinstitute.clr.events/page/2221-marineinstitute/691-book-of-abstracts?ev=133655

Other dissemination and communication activities

- EuroSea/OceanPredict 1st Workshop in June 2022
- Presentation of Analysis of hard and soft law frameworks and mechanisms to enable adequate adaptation of ocean observing system design at a regional and global level at the United Nations in June 2022, first in New York and then at the UN Ocean Conference in Lisbon in June 2022

- Presentation of glider task achievements at UG2 Workshop Seattle ’22, USA, in September 2022
- Joint 2nd European FerryBox workshop in Geesthacht, Germany on 27-28 September 2022, organized in collaboration with EuroGOOS and JERICO-S3
- 7th Argo Science Workshop in Brussels, on 11-13 October 2022
- HFR Radar Task Team workshop in November 2022
- EuroSea 3rd Anniversary Webinar in November 2022
- Foresight workshop on the sustainability of the ocean observing and forecasting system at the Museum of Natural Sciences, Brussels, on 15-16 March 2023
- 2nd EuroSea Tide Gauge Network workshop (hybrid event) held at EPPE, Madrid, and virtually on 4 - 5 May 2023
- Presentation of EuroSea’s vessels task and network at the WMO/UNESCO Ship Observations Team 12th session in Melbourne, Australia on 16-18 May 2023
- EuroSea/OceanPredict 2nd Workshop in July 2023
- International Marine Debris Data Harmonization workshop in Yokohama, Japan in August 2023
- Organization of OceanPractices OBPS Workshop VI in October 2022 and the OBPS Workshop VII in September 2023
- Presentation of Foresight workshop outcomes at the workshop on ocean observation of the EU Sustainable Blue Economy Partnership on 27 September 2023 in Brussels
- Presentations of different tasks at EuroGOOS conference in Galway in October 2023
- Révelard, A., Cocquempot, L., Organisational Best Practices to foster cooperation between disciplines/platforms/networks. Ocean Best Practices Newsletter of December 2022
- ASV (task 3.7) presentation and representation at iXBlue Seminar on ASV in May 2022 (online), Autonomous Ship Expo in June 2022 (online), MTI Marine Robotics Summer School in July 2022 (online), International Symposium on Marine Sciences 2022 in July 2022 in Gran Canaria, IMO Seminar on Development of a Regulatory Framework for Maritime Autonomous Surface Ships - MASS in September 2022 (online), Jornada Tecnica sobre Buques Autonomos DGMM in October 2022 in Madrid, Glider School 2022 in October 2022 in Gran Canaria, MATS 2022 in November 2022 in Southampton, AINE 2022 in November 2022 in Madrid, 8th UK MASS Conference in January 2023 (online), iXblue Conference in January 2023 in Edinburg, Oceanology Americas 2023 in February 2023 in San Diego, OASIS Webinar Series in March 2023 (online), MCDEE 2023 Conference in April 2023 in London, Ocean Business 2023 in April 2023 in Southampton, OASIS Webinar Series in April 2023 (online), 2nd EuroSea USV Workshop in May 2023 in Gran Canaria, Oceans 2023 IEEE/MTS in June 2023 in Limerick, MARTECH 2023 in June 2023 (online), Autonomous Ships Conference in June 2023 in Amsterdam, MIT Summer School in July 2023 (online), Oceans 2023 IEEE/MTS in September 2023 in Biloxi, EuroGOOS Conference 2023 in October 2023 in Galway, Glider School 2023 in October 2023 in Gran Canaria
- OSPAC demonstration at Barcelona harbour in March 2023 (hard launch), EuroSea 3rd Anniversary Webinar, COSS-TT Coordination meeting, and PredictOnTime: First Workshop on Observing and Predicting the Global Coastal Ocean in May 2023, EuroSea Day at Ocean Race Genoa 2023
- Project (re)presentation by the project coordinator: The open informal consultative process by UNCLOS at the UN headquarters in New York in June 2022, The Ocean Conference in Lisbon in June 2022, Malizia Ocean Festival in Hamburg in September 2022, EU-Canada Ocean Partnership in Brussels in October 2022, GCOS Science Conference in Darmstadt in October 2022, GEO Week in Accra in November 2022, UNFCCC COP27 in Sharm el Sheik in November 2022, G7 FSOI in Berlin in

November 2022, EuroGEO meeting in Athens in December 2022, European Maritime Day in Brest in May 2023, The Ocean Summit in Aarhus in June 2023, Digital Ocean Forum in Brussels in June 2023, WCRP/GCOS climate cycle workshop in Paris in June 2023, IOC Assembly in Paris in June 2023, EuroSea final conference and side-meetings in Paris in September 2023, Sustainable Blue Economy Partnership meeting in Brussels in September 2023, EuroGOOS conference in Galway in October 2023, WCRP Open Science Conference in Kigali in October 2023

All public EuroSea deliverables are available on the EuroSea website[119]

Conclusion

At the time of writing this deliverable, EuroSea is coming close to an end, with only a few deliverables and milestones left to report on. Although the grant agreement foresaw that only WP9 should be active during the last 2 months of the action, these extra months are being used by a few partners to buffer delays due to the COVID-19 pandemic and/or Brexit. Although the action experiences some delays due to those circumstances, EuroSea was able to keep to the original time-line and it was not necessary to ask for extension of the project.

Overall, the success of EuroSea can best be seen by the about 100 impacts that are described on the EuroSea website. In addition, obviously, EuroSea has created numerous long-lasting results and outputs. One important aspect of EuroSea with 50+ partners is building of trust and connections between the partners and the stakeholders we have been working actively with.

Despite reaching the objectives of EuroSea, we realized that a lot more is needed before we reach the vision articulated by EuroSea. However, EuroSea has made substantial progress and has improved the ocean observing and forecasting system in Europe and globally.

[119] https://eurosea.eu/

References

References were given as foot notes.

List of partners

Table 1. List of EuroSea beneficiaries

Acronym	Name of Organisation	Link
GEOMAR	GEOMAR HELMHOLTZ-ZENTRUM FÜR OZEANFORSCHUNG KIEL	https://www.geomar.de/en/
EuroGOOS	EUROGOOS	www.eurogoos.eu
IOC/UNESCO	UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANISATION	www.ioc-unesco.org
MOI	MERCATOR OCEAN INTERNATIONAL	https://www.mercator-ocean.fr
UNIBO	ALMA MATER STUDIORUM – UNIVERSITÀ DI BOLOGNA	https://www.unibo.it/en/homepage
MI	MARINE INSTITUTE	https://www.marine.ie/Home/home
CSIC	AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS	http://www.csic.es/home
ENS	ECOLE NORMALE SUPERIEURE	https://www.ens.fr/en
CLS	COLLECTE LOCALISATION SATELLITES SA	https://www.cls.fr/
OGS	ISTITUTO NAZIONALE DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE	www.inogs.it
CMCC	FONDAZIONE CENTRO EURO-MEDITERRANEO SUI CAMBIAMENTI CLIMATICI	www.cmcc.it
UiB	UNIVERSITETET I BERGERN	www.uib.no
SU	SORBONNE UNIVERSITE	http://www.sorbonne-universite.fr
SOCIB	CONSORCIO PARA EL DISENO, CONSTRUCCION, EQUIPAMIENTO Y EXPLOTACION DEL SISTEMA DE OBSERVACION COSTERO DE LAS ILLES BALEARS	http://www.socib.eu/
ECMWF	EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS	https://www.ecmwf.int
IO PAN	INSTYTUT OCEANOLOGII POLSKIEJ AKADEMII NAUK	http://www.iopan.gda.pl/
IfW	INSTITUT FÜR WELTWIRTSCHAFT	https://www.ifw-kiel.de/
Euro-Argo ERIC	EURO-ARGO ERIC	https://www.euro-argo.eu/
CNRS	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE	https://www.cnrs.fr
IFREMER	INSTITUT FRANCAIS DE RECHERCHE POUR L'EXPLOITATION DE LA MER	https://www.ifremer.fr/en
RBINS	INSTITUT ROYAL DES SCIENCES NATURELLES DE BELGIQUE	www.naturalsciences.be
ISPRA	ISTITUTO SUPERIORE PER LA PROTEZIONE E LA RICERCA AMBIENTALE	http://www.isprambiente.gov.it/en?set_language=en
IEEE	IEEE FRANCE SECTION	https://www.ieeefrance.org/
EMB	EUROPEAN MARINE BOARD IVZW	www.marineboard.eu
IMT	INSTITUT MINES-TÉLÉCOM	https://www.imt.fr/en/
AZTI	FUNDACIÓN AZTI - AZTI FUNDAZIOA	www.azti.es
EPPE	PUERTOS DEL ESTADO	www.puertos.es
ACRI	ACRI-ST SAS	https://www.acri-st.fr/
ARUP	OVE ARUP & PARTNERS INTERNATIONAL LIMITED	https://www.arup.com
HCMR	HELLENIC CENTRE FOR MARINE RESEARCH	https://www.hcmr.gr/en/
NIVA	NORSK INSTITUT FOR VANNFORSKNING	https://www.niva.no/en/
Met Office	MET OFFICE	https://www.metoffice.gov.uk

Acronym	Name of Organisation	Link
EMSO ERIC	EUROPEAN MULTIDISCIPLINARY SEAFLOOR AND WATER COLUMN OBSERVATORY - EUROPEAN RESEARCH INFRASTRUCTURE CONSORTIUM	http://emso.eu
PLOCAN	CONSORCIO PARA EL DISEÑO, CONSTRUCCIÓN, EQUIPAMIENTO Y EXPLOTACIÓN DE LA PLATAFORMA OCEANICA DE CANARIAS	www.plocan.eu
UBREMEN	UNIVERSITAET BREMEN	https://www.marum.de/en/index.html
UPORTO	UNIVERSIDADE DO PORTO	https://lsts.fe.up.pt
SZN	STAZIONE ZOOLOGICA ANTON DORHN	http://www.szn.it/index.php/en/
AWI	ALFRED-WEGENER-INSTITUT, HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG	www.awi.de
ETT	ETT SPA	https://www.ettsolutions.com
Nologin	NOLOGIN CONSULTING, S.L.	https://www.nologin.es
UPC	UNIVERSITAT POLITECNICA DE CATALUNYA	https://lim.upc.edu
DMI	DANMARKS METEOROLOGISKE INSTITUT	http://www.dmi.dk
TalTech	TALLINNA TEHNIKAULIKOOL	http://www.ttu.ee/
CNR	CONSIGLIO NAZIONALE DELLE RICERCHE	http://www.ismar.cnr.it
IRD	INSTITUT DE RECHERCHE POUR LE DÉVELOPPEMENT	www.ird.fr
UCAM	THE CHANCELLOR MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE	https://www.cam.ac.uk
XYLEM	XYLEM AANDERAA DATA INSTRUMENTS AS	https://www.xylem.com/
WMO	ORGANISATION METEOROLOGIQUE MONDIALE	www.wmo.int
UERJ	UNIVERSIDADE DO ESTADO DO RIO DE JANEIRO	www.uerj.br
UFPE	UNIVERSIDADE FEDERAL DE PERNAMBUCO	https://www.ufpe.br
MUN	MEMORIAL UNIVERSITY OF NEWFOUNDLAND	www.mun.ca
DAL	DALHOUSIE UNIVERSITY	https://www.dal.ca/diff/cerc.html
NOC	NATIONAL OCEANOGRAPHY CENTRE	https://noc.ac.uk